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Aeronautics and Space Report of the President

1984 Activities

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Aeronautics and Space Report of the President

1984 Activities

National Aeronautics and Space Administration
Washington, D.C. 20546

A great blue heron, startled from its perch in a lagoon south of the Launch Pad A of Launch Complex 39 at the Kennedy Space Center (KSC), moments before Discovery, seen in the background, was launched on its maiden voyage.

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Summary

The year 1984 was one of high achievement for the United States aeronautics and space programs. It also was a time in which new space goals were established, setting the Nation's course in this vast frontier for the rest of this century.

This new pathway in space was charted by President Reagan on January 25, 1984, in his State of the Union message to the Congress. Noting that the U.S. space effort, little more than a quarter of a century old, has transformed dreams into reality, the President proposed a new space goal, directing the National Aeronautics and Space Administration (NASA) "to develop a permanently manned space station . . . within a decade." The establishment of a permanent human habitat in space, the President said, holds enormous potential for commerce both on earth and in space; and to meet this challenge, President Reagan called for NASA's help to encourage investment in space by the private sector, stating that a number of Executive initiatives would be forthcoming to advance this objective.

A month later, on February 24, 1984, the President announced the first of the promised initiatives and issued Executive Order 12465 to "encourage" the development of commercial expendable launch vehicle operations by private U.S. enterprises. The Department of Transportation, assigned responsibility for this effort, is to be assisted by an interagency group, including NASA. Six months later, on July 20, 1984, President Reagan gave an additional boost to commerce in space by announcing his National Policy on the Commercial Use of Space, which calls for economic initiatives, legal and regulatory initiatives, research and development initiatives, and initiatives to implement generally this new national policy.

The commercial potential of space, emphasized by the Administration, was advanced in 1984 by the success of Space Shuttle operations, precursor to development of a fully operational Space Transportation System (STS). Of the STS' 1984 flights, three were flown by Challenger (the second craft of the STS fleet) and two by Discovery (the first flights of this third craft of the STS). Each Shuttle mission deployed operational satellites into Earth orbit for academic, industry, U.S. government, and foreign government users. The satellite-launch services were provided on a reimbursable basis, except for missions launched by or for the U.S. government. Each mission also included experiments, from several disciplines, which were performed aboard the Shuttle.

Several communications satellites were deployed for paying customers by means of expendable launch vehicles, as well as by the Shuttle. Special satellites, such as the Long Duration Exposure Facility and the national climate research satellite, Earth Radiation Budget Satellite, also were deployed from Shuttle orbiters. Other highlights of Shuttle missions in 1984 included the first use of the Manned Maneuvering Unit; the first retrieval and return to Earth of disabled satellites, the Westar-6 and Palapa B2 communications satellite, in November; and the capture, repair and redeployment of the Solar Maximum Mission satellite in April. The first Discovery mission carried the first non-astronaut crew member. The third Challenger mission of 1984, which began on October 5, carried a crew of 7, the largest to date, including for the first time a Canadian payload specialist. Two female mission specialists also were on board. During 1984, a total of four female mission specialists were on Shuttle flights.

In 1984, U.S. payloads launched into Earth-orbit numbered 35. Of the 35, 14 were launched by the Department of Defense (DoD) and 21 by NASA, including 9 satellites and a balloon rendezvous radar target that the Shuttle deployed during its 5 flights. Expendable launch vehicles boosted 20 satellites into orbit, with one launching 3 satellites simultaneously and another launching 2.

NASA launched 11 communications satellites, 10 of which were for commercial customers and one of which was defense related. Other applications spacecraft also were boosted into orbit: 3 navigation satellites, 1 navigation balloon, 1 NOAA weather satellite, 1 Earth resources satellite, and 5 scientific satellites.

In the exploration of the solar system in 1984, cometary studies had a prominent role, with the International Cometary Explorer spacecraft retargeted toward a 1985 encounter with the Comet Giacobini-Zinner and with preparations underway for observations of Comet Halley during its appearance in 1985-1986. Four active planetary spacecraft, Pioneers 10 and 11 and Voyagers 1 and 2, continued to provide observations of the interplanetary medium. Data from Pioneer 10 were transmitted from a distance of nearly 35 astronomical units (AU) from the sun in a direction opposite the solar apex. Data from a distance of 17 AU were provided by Pioneer 11 from the direction of the solar apex. Additional observations of the interplanetary medium came from Voyagers 1 and 2. Study of the inner solar system continued with the fifth year of the Pioneer Venus Orbiter mission; and the Galileo spacecraft had its final testing in 1984 in preparation for its 1986 launch.

NASA's program of international cooperation continued in 1984. On February 6, NASA launched a communications satellite for Indonesia from the orbiter Challenger. When the satellite's booster motor failed, the orbiter Columbia later retrieved the satellite and returned it to Earth for repair. In November 1984, a communications satellite was deployed from the orbiter Discovery for Telsat Canada; and on November 14, 1984, a NATO defense related satellite was put into orbit successfully by an expendable launch vehicle (ELV). There also were launches for the United Kingdom and the Federal Republic of Germany. During the year, the COSPAS/SARSAT search and rescue system became operational, another example of productive international cooperation, this time in the safety field.

In response to the President's National Space Policy for assured access to space (August 1984), DoD began plans to acquire a limited number of ELVs to complement NASA's STS. The ELVs are intended to serve as a complement to the Space Shuttle and will be capable of launching Shuttle-class DoD payloads essential for national security. Efforts by DoD to increase the survivability, autonomy, performance, reliability and functional life of military space-based communications systems continued in 1984.

During 1984, NASA, DoD, and the Federal Aviation Administration continued to work for improved performance and safety of aircraft. NASA research also addressed the objective of better performance in the STS and application satellites as well as increased safety in space travel.

Following is a summary by function of U.S. space and aeronautics activities and achievements in calendar year 1984. Succeeding chapters delineate the programs and accomplishments of the various individual agencies in greater detail.

Communications

In 1984, prompted by evident growing congestion of the frequency spectrum and the erosion of the U.S. competitive position in satellite communications technology resulting from inroads made by Europe and Japan, NASA undertook a program, in cooperation with U.S. industry, to develop high risk technology for the desired multiple frequency bands and other requirements necessary to maintain U.S. preeminence in the world marketplace. For this objective, NASA began development of the Advanced Communications Technology Satellite (ACTS), the agency's first experimental communications satellite since 1973. In 1984, NASA also initiated a technology development program to provide a variety of satellite-aided mobile communications for cars, trains, buses, and other mobile platforms—such services as emergency response communications for law enforcement, assessment of natiural disasters, local and national emergencies, and emergency medical services as well as for a variety of business and commercial uses. NASA also consulted with other government agencies to determine the usefulness of mobile satellite services for their operations.

The use of international and domestic satellite communications increased in 1984 as demand for such communications continued to grow. During 1984, NASA launched 11 communications satellites, 7 from the Space Shuttle and 4 by ELVs. Four of the satellites were for international use.

Operational Space Systems

COSPAS/SARSAT. In October 1984, the international satellite aided search and rescue system, COSPAS/SARSAT, developed by the United States, Canada, France, and the Soviet Union, became operational; and a Memorandum of Understanding was signed by representatives of the nations involved. Other nations participating in this operation are Norway, the United Kingdom, Sweden, Finland, Bulgaria, Denmark, and Brazil. Their participation has both reduced costs to individual participants and broadened the sharing of benefits, the most important being the saving of lives, at least 289 throughout the world since development of the system began.

INTELSAT and INMARSAT. The 108-member-nation International Telecommunications Satellite Organization (INTELSAT) continued to expand its services in 1984. The INTELSAT network, consisting of 17 satellites positioned over the Atlantic, Pacific, and Indian Oceans, was reconfigured for improved and more efficient operations. The Federal Communications Commission (FCC) approved 11 new Earth station facilities, which will provide the INTELSAT system access in the Atlantic Ocean Region for international business service, and authorized Comsat, the U.S. member of INTELSAT, to participate in the construction of five INTELSAT VI satellites, to be built by Hughes Aircraft Company.

In 1984, in its third year of operation, the International Maritime Satellite Organization (INMARSAT) had three satellites to serve the Atlantic, Pacific, and Indian Ocean regions and a lease agreement with INTELSAT to provide martitime communications services through 1985. With its facilities, INMARSAT served 2,800 vessels. In 1984, as in 1983, INMARSAT requested proposals from industry for additional maritime capability. The International Civil Aeronautics Organization (ICAO) approached INMARSAT in 1984 to investigate the possibility of shared use of satellite facilities; and INMARSAT subsequently specified the inclusion of a small part of the aeronautical mobile-satellite band in INMARSAT's second generation satellites, for which bids were under evaluation in 1984.

Domestic Communications Satellites. In 1984, domestic commercial communications satellites increased in number from 16 to 23. Four satellites were retired and replaced with satellites of higher efficiency. The Federal Communications Commission (FCC) has authorized the launch of and assigned orbital postions for a total of 38 domestic satellites; and there are an additional 85 applications on file with the FCC for new domestic satellites. Those applicaitons are under review with respect to the reduced orbital spacing requirement the FCC approved in 1983. The additional applications are from a mixture of new satelltie applicants, applicants for expansion of existing and planned systems, and applicants for replacement satellites in existing systems. New technology continued to bring economic benefits and improved satellite services to users. Four of the 8 companies granted permits by the FCC to construct Direct Broadcast Satellites (DBS) have been granted modified construction permits and launch authority. The remaining 4 have had their permits cancelled for failure to comply with the terms of those permits. Three additional applicants on a "second-round" cut-off list have been joined by 4 more, each proposing delivery of 6 to 16 channels from each of 2 satellites.

Military Communications Satellites. Military Satellite Communications (MILSATCOM) continued to meet the challenge of an unsettled and uncertain world and the increasingly destructive nature of weapons by providing rapid, reliable communications crucial to the deterrence and containment of hostilities. Reliable communications are absolutely essential in times of political-military crisis to reduce danger and the threat of conflict that might result without such communications. MILSATCOM provides near instant links between command and support, strategic and tactical, nuclear and conventional decision makers, and forces deployed worldwide. Its effective operation depends primarily on the Defense Satellite Communications Systems, the Fleet Satellite Communications System, and selected commercial satellite communications circuits, as well as on the operational Air Force Satellite Communications System (AFSATCOM). Development by the Air Force of the MILSTAR communications satellite and terminals for all airborne platforms continued in 1984 with the Navy responsible for shipboard terminals and the Army for all other general terminal requirements for the three services. By the end of 1984, most of the terminal development by the Air Force was complete; and work was proceeding on terminals of the other services with emphasis on compatibility for interoperations.

Military Navigation Satellites. Nova-3, the second improved Transit satellite for DoD, was launched successfully in October 1984. Navstar 9 and 10, joint service Global Positioning System (GPS) satellites, also were launched successfully, Navstar 9 in June and Navstar 10 in September 1984. The function of GPS is to provide radio position and navigation information for DoD missions worldwide. With its third year of development completed in 1984, the system is being built under a multi-year contract for 28 spacecraft. Approximately one-third of the contract has been accomplished, and estimates are that the GPS will achieve full operational capability by the end of 1988.

National and international efforts for a Future Global Maritime Distress and Safety System (FGMDSS) continue. Satellite emergency-position-indicationg radio beacons will provide initial distress-alerting information from ships in distress to shore-based rescue coordination centers. According to present plans, those beacons will operate through the geostationary INMARSAT and the now-operational polar COSPAS/SARSAT satellite systems. Expectations are that the FGMDSS will be fully implemented by 1996.

Work continues by NASA, industry, and other government agencies to develop commercial land-mobile services for emergency communications (police, medical, natural, and other disasters) as well as for health, education, and other public and social service communications to remote areas.

Research also continues on reducing further the orbital spacing between domestic satellites in specified frequency bands in order to accommodate additional satellite systems. NASA and industry continue to develop new and advanced technologies for future, more advanced communications systems. One such new development, for example, offers a tremendous increase in voice channels, with enormous commercial potential.

Earth: Atmosphere, Environment and Resources

In 1984, observations and knowledge of Earth, its atmosphere, environment, and resources, were advanced substantially by several special satellite systems, programs, and experiments. NASA's Shuttle mission of October 1984 carried 2 major land sensing experiments: the Shuttle Imaging Radar and the Large Format Camera. It also carried the Earth Radiation Budget Satellite (ERBS), which was deployed into orbit from the Shuttle. ERBS is the first part of a three-satellite system comprising the Earth Radiation Budget Experiment (ERBE) and is important to NASA's continuing climate observing program, whose objective is to gain understanding of the important physical proc-

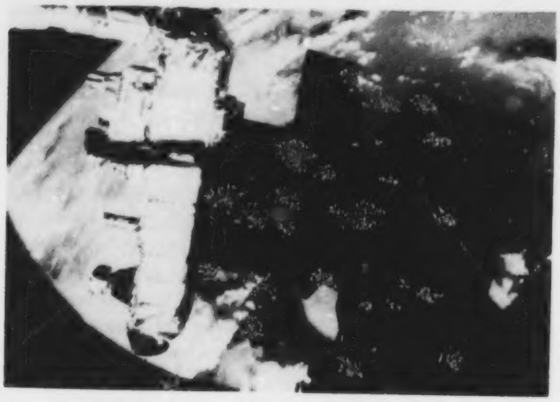

Photo taken onboard the Shuttle Challenger mission showing the Earth Radiation Budget Satellite (ERBS) prior to its deployment on October 5, 1984. Part of the arm of the remote manipulator system can be seen grasping the satellite.

esses governing the interaction of clouds and radiation. Such knowledge is essential for accurate climate modeling and prediction. Toward this objective, the World Meteorological Organization and the International Council of Scientific Unions jointly sponsored an International Satellite Cloud Climatology Project (ISCCP). NASA is a key participant as host to the Global Processing Center, where data and cloud imagery from the 6 operational meteorological satellites are merged and analyzed.

In cooperation with the National Oceanic and Atmospheric Administration, the National Science Foundation, and the Department of Energy, NASA also established the National Project Office for the First ISCCP Regional Experiment (FIRE). Both ISCCP and FIRE will aid in the interpretation of ERBE measurements.

The study of atmospheric processes also benefited in 1984 from the use of laser radar to observe global wind profiles and thereby improve understanding of large-scale atmospheric processes necessary for better weather prediction. Other significant developments were the use of satellite radar data to determine wind speed and direction of the ocean surface and NASA's Mesoscale Atmospheric Research Program which deals with studies of atmospheric behavior related to severe weather. In 1984, several such studies were made to increase airline safety; and the use of airborne Doppler Light Detection and Ranging (LIDAR) laser systems also contributed to improving airline safety by advancing pilots' understanding of the effects of wind on flight.

In 1984, NASA also completed the first phase of a research-aircraft-based effort, the Global Tropospheric Experiment/Chemical Instrumentation Test Evaluation, and continued work on its Upper Atmosphere Research Satellite scheduled for launch in 1989.

The 3-satellite Active Magnetosphere Particle Tracer Explorer, on which NASA, the Federal Republic of Germany, and the United Kingdom cooperated, was launched in August 1984. The objective of the NASA satellite, the Charge Composition Explorer, was to detect ions within Earth's magnetosphere. The Ion Release Module (IRM) of the Federal Republic of Germany was placed in a highly elliptical orbit to study Earth's magnetosphere; and the United Kingdom Satellite was launched to observe barium and lithium released by IRM. Results obtained from each of the spacecraft are under analysis. Programs and strategies were formulated for monitoring changes in stratospheric ozone, including a major aircraft measurement program using the NASA U-2 and ER-2 high-altitude aircraft, to study atmospheric transfer processes.

New data, including those from the first direct measurement of the movement of tectonic plates that make up the Earth's crust and measurement of a change in the gravity field of Earth, were obtained in 1984 from NASA's Geodynamics Program using laser ranging to satellites such as the Laser Geodynamics Satellite. Such measurements are vital to the Earthquake Hazard Reduction Program of the U.S. Geological Survey. NASA cooperated with other nations concerned with the hazard of earthquakes, providing measurements made in the Mediterranean, the Caribbean, the Near East, South America, and western Canada.

Important to environmental studies in 1984 were NOAA's satellites, GOES 5 and 6, prime imaging spacecraft of the Geostationary Operational Environmental Satellite (GOES) system. On July 30, the imager failed on GOES 5; and GOES 6 was repositioned to compensate and to provide necessary coverage. Failure of GOES 5 did not affect the Data Collection System, its Space Environment Monitor, or its Weather Facsimile broadcasting capability. Additional GOES spacecraft, scheduled for launch in 1985 and 1986, will incorporate improvements such as concurrent imaging and atmospheric sounding and relocation of picture elements for better calculation of winds from images showing cloud motions.

In 1984, the Earth observation system consisted of two Earth-orbiting satellites, Landsat 4 launched in 1982 and Landsat 5 launched in 1984, and a control and data processing facility at Goddard Space Flight Center. Testing of sensor systems to discriminate surface materials continued. Originally developed by NASA, Landsat 4 now is under NOAA management, as is Landsat 5, as a result of a 1983 Presidential Directive. Both satellites carried special Earth-observation sensor packages: the multi-spectral scanner to measure solar radiation and the thematic mapper to make measurements in the visible and near-infrared wave lengths. Data from Landsat are distributed through the Department of Interior's Earth Resources Observations System Data Center, Sioux Falls, South Dakota, and through foreign facilities in countries with Landsat ground stations. During 1984, through an agreement with the Department of the Interior, NOAA added 33,000 multi-spectral scanner scenes and 4,000 thematic mapper scenes to its archives. Some 3,000 digital products and 35,000 photographic products were sold to Landsat customers at prices to recover the cost of operating and managing the Landsat system.

Public Law 98-365, passed by the Congress in July 1984 with respect to newly evolving commercial relationships, required the Department of Commerce's Civil Space Remote Sensing Commercialization Group to report to the Congress before implementing the Secretary of Commerce's decision to contract for commercialization of the Landsat system. The law and the subsequent report advanced the Administration's efforts to move civil satellite remote sensing from the public sector into the private sector. However, the President concurred in a decision by the Secretary of Commerce and the Office of Management and Budget to limit government financial support for the transition of Landsat operations to the private sector so as not to affect adversely the Administration's efforts to reduce the Federal Budget.

The Congress had not supported the Administration's 1983 proposal for commercialization of civil weather satellites affirming that those satellites support traditional government roles for the health, safety, and economic well-being of its citzens. It should be noted that P.L. 98-365 reaffirmed the priority of those traditional roles in the context of newly evolving government-commercial relationships.

It has been said that the U.S. weather satellites alone are well worth the U.S. investment in space. The advanced instruments in NOAA's meteorological satellites are able to provide a variety of services, including environmental observations of the entire Earth and meteorological measurements yielding improved conventional and numerical weather prediction. At the end of 1984, the latest weather satellite, NOAA-9, was launched. Its 3-instrument array of sensors measures Earth-radiation budget factors, including backscatter to space of solar ultraviolet light and Earth-radiated thermal (infrared) radiation. NOAA-9 will work in concert with NASA's Earth Radiation Budget Satellite. As part of the COSPAS/SARSAT system, NOAA-9 also carries search and rescue instrumentation.

Observations via satellite of oceanic processes were made to assess the interdependence of atmospheric and oceanic variability and its influence on Earth's climate. The Navy continued development of its Remote Ocean Sensing System (N-ROSS) satellite which, with the cooperation of NOAA, NASA, and the Air Force Systems, will measure ocean surface winds, sea surface temperatures, movement and height of waves, and polar ice conditions for both civil and military purposes. A Navy oceanographer was aboard the Shuttle Challenger's October 1984 mission to observe and record ocean phenomena from low Earth orbit.

In 1984, data from space contributed to ongoing programs to assess agricultural crop conditions and to manage renewable resources and land use. The Department of Agriculture emphasized its multiagency program, Agriculture and Resources Inventory Service through Aerospace Remote Sensing; data from NOAA and Landsat satellites contributed substantially to inventory and management of land resources and land use.

In the Spacelab Flight Program, significant observations of the environment were made. For example, in the mission of October 1984, Shuttle Imaging Radar B and the Large Format Camera were used for observations and returned outstanding images. In one experiment of that mission, the global distribution of carbon monoxide in the atmosphere was measured; and another experiment demonstrated a capability for discriminating between cloud cover, water, vegetation, and bare ground.

Enviromental concerns with respect to pollution were addressed by the Environmental Protection Agency (EPA) assisted by NASA. NASA helped EPA develop various Light Detection and Ranging laser systems for monitoring the environment.

Space Science, Space Research and Technology

NASA's space science and space research and technology programs are key to U. S. primacy in the exploration of space and in the knowledge gained. In 1984, new scientific discoveries were made as both research and technology continued to advance.

Space Science

Planetary spacecraft Pioneers 10 and 11 and Voyagers 1 and 2 provided observations in 1984 of the interplanetary medium; and study of the inner solar system continued with observations from the Venus Orbiter, a mission in its fifth year. Final testing of the Galileo spacecraft was conducted in preparation for its mission to Jupiter in 1986. Other planetary missions were approved and under development, including the Venus Radar Mapper, to be launched in 1988, and the Mars Geoscience Climatology Observer, for launch in 1990 to study the Martian climate and soil atmospheric interaction for a full Martian year, approximately 700 Earth days.

Cometary studies also were prominent in 1984. The International Cometary Explorer (ICE) was set on a path to a 1985 encounter with Comet Giacobini-Zinner; and preparations were made for using the

Shuttle Astro-1 payload to observe Comet Halley in 1985-86.

The NASA Astrophysics Program continued investigation of the physical nature of the universe. Perhaps the most dramatic increase in astrophysical knowledge in 1984 came from the Infrared Astronomical Satellite, launched in 1983. More than 98 percent of the sky was covered at least twice; and a catalog of more than 200,000 infrared sources was issued in November 1984 as a result of data analysis. Previous catalogs had only 1,000 such entries. Also of note in 1984 were the 3 Active Magnetospheric Particle Tracer Explorers (AMPTE) launched in August. Development of the Cosmic Background Explorer (COBE) continued in 1984 with instrument development. Launch is planned for the end of 1988.

Technology research and long-range planning for the proposed Advanced X-ray Astrophysics Facility began in 1984. Mirror technology demonstration programs were continued. Investigators for the proposed Space Infrared Telescope Facility were selected, and design of the proposed Solar Optical Telescope was continued. The Hubble Space Telescope, a major astronomical observatory and the first space facility designed and built from inception to be serviced on orbit by the Shuttle orbiter, is on schedule for launch in the second half of 1986. Expectations are that the on-orbit serviceability will be such as to obviate the necessity for ever returning the Hubble Space Telescope to Earth for refurbishment.

In 1984, NASA's High Energy Astronomy Observatories (HEAOs) provided significant results on a broad range of astrophysical phenomena. Of particular significance is firm evidence, provided by the High Resolution Gamma Ray Spectrometer on HEAO-3, of the recent processing of heavy nuclei in stars. HEAO-2 also yielded a new finding: a spectrum of a BL Lacerta object revealed a sharp absorption feature. BL Lacerta objects are thought to be a variety of quasars and will be primary objects of study by instruments on the Gamma Ray Observatory (GRO), which is scheduled for launch in 1988. Preliminary design review of GRO was completed in 1984, as were design reviews of its instruments.

In 1984, the Solar Maximum Mission spacecraft was repaired in orbit by the crew members of the Space Shuttle. This was the first use of new technology for repairing spacecraft in orbit. Improvements incorporated during the repair made possible some new and revealing observations of the structure and dynamics of solar prominences.

The year 1984 was significant for each of the four elements of NASA's suborbital program: balloons, Spartan, rockets, and the Kuiper Airborne Observatory (KAO). Balloons carried high-resolution gamma ray telescopes above the atmosphere to observe the annihilation of antielectrons in the center of our galaxy. The first Spartan carrier was ready for flight in 1984 but was rescheduled to 1985; and a Spartan carrier was under development for observation of Comet Halley in 1986. A major campaign to study plasma physics in space with sounding rockets began in Greenland in December 1984 and will continue through February 1985. The KAO carried a 1-meter telescope for infrared and submillimeter observations above the absorbing water vapor in Earth's atmosphere. There were 35 successful balloon launches, 38 successful rocket launches, and 64 missions (511 hours of flight time) with the KAO.

Microgravity Science

In 1984, several developments took place in microgravity science and applications. In July, NASA transferred to the National Bureau of Standards (NBS), for evaluation, characterization, and ultimate sale, the 10-micron diameter monodisperse latex beads processed aboard the Space Shuttle. They are to be released for sale in 1985 as primary standards. NBS also began evaluation of 30-micron diameter beads produced in limited quantities in 1984 on a Shuttle flight. Preliminary results were obtained in 1984 from a germanium selenide vapor crystal growth experiment. Typical of crystals processed in space, they are larger and more regular and have a low defect density.

In 1984, McDonnell Douglas Aerospace Corporation continued efforts to commercialize processing of biomaterials in space using a Continuous Flow Electrophoresis System.

Life Sciences

In the life sciences, studies continued in space medicine and space biology. In space medicine, emphasis continued on the health and safety of spacecraft crews, including the effect of various aspects of Shuttle operations, the refinement of medical standards, criteria for crew selection and crew medical training, and monitoring and maintenance of the health and career longevity of space travelers. Particular attention was given to the Space Adaptation Syndrome and medical concerns of both long-term and short-term space missions. These concerns include changes in perception, cardiovascular dynamics, neuromuscular physiology, and radiation exposures.

In space biology, ground-based and Spacelab-1 flight experiments with plants added significantly to knowledge of plant growth control and mechanisms. For example, a spaceflight experiment proved that the phenomenon of continuous circular oscillation exhibited by all plant shoot tips is gravity independent, thus settling a scientific question debated since the time of Charles Darwin. In 1984, ground-based animal experiments provided important information on animal vestibular, skeletal, and muscular systems. Preparation continued for special experiments on fundamental problems of space biology to be conducted on

Spacelab-4. Flight hardware for that first dedicated Space Life Sciences mission was delivered in 1984 to various NASA centers for testing.

Studies continued in 1984 on the origin, evolution, and distribution of life and life-related chemicals on Earth and throughout the universe; and investigations on the influence of biological processes on global biogeochemical cycles continued in NASA's Biospheric Research program, formerly Global Biology.

Space Research and Technology

Advances in space exploration and space science develop concurrently with advances in research and technology. Conducted at NASA centers, and in industry and universities, NASA's research and technology program is broad-based, covering several disciplines, including propulsion, space energy conversion, controls and human factors, space data and communications, computer science and electronics, materials and structures, and aerothermodynamics. The program includes both theoretical and experimental research, with the latter conducted both in the laboratory and in flight tests.

In propulsion, advances were made in 1984 in developing longer life components and critical subcomponents for Earth-to-orbit propulsion systems.

In space energy conversion, a joint DOE/DoD/NASA nuclear reactor program has concentrated most recently on the evaluation of 3 energy systems: thermoelectric, thermionic, and Stirling-cycle conversion systems. During 1984, research progressed on photovoltaic energy systems in high-performance solar cells and large arrays, and provided increased efficiency and decreased weight. Progress also was made on multiple bandgap cells. Large electric currents and heat flows required for future advanced space systems also were investigated, as was the problem of disposal or transfer into space of waste heat from a space station power system. The concept of regenerative fuel cells for power generation and energy storage also was tested.

Controls and human factors research focused largely on controlling space systems and on investigation of advanced concepts for teleoperations, the largest portion of the human factors program. Major accomplishments in 1984 were made in intelligent displays and augmented controls for use by an operator.

Benefits to the space data and communications area in 1984 resulted from development and demonstration of a charge coupled device for imaging astronomical objects. Also demonstrated in 1984 for the first time was a 55-meter diameter, offset wrap-rib antenna capable of supporting a nationwide mobile communications system.

Advances in computer science and electronics were made in 1984 by an interagency research and development program involving NASA, DOE, the U.S. Air Force, the Central Intelligence Agency, and the Defense Mapping Agency, all working together to provide both the Space Station and government supercomputer facilities with an ultra-high performance data storage unit.

Materials and structures research in 1984 yielded a new and more durable thermal protection system than the original system for the Shuttle orbiters. Over an area of 4,000 square feet, 2,000 flexible, woven ceramic blankets replaced 8,000 ceramic tiles without an additional weight penalty or loss of performance.

In aerothermodynamics, progress was made in defining the aerodynamic heating likely to be encountered by orbital transfer vehicles, transatmospheric vehicles and planetary return vehicles using aerobraking and aerocapture for maneuvering or for braking upon return to Earth.

Research and technology space flight experiments in 1984 included two significant events in the use of the Shuttle: the delivery of the Long Duration Exposure Facility into orbit in April 1984 from the Shuttle Orbiter Challenger; and the lifting of 3 experiments on space power technology in one payload by the Shuttle orbiter Discovery in August and September 1984. At the heart of the latter payload was a lightweight, flat-folding solar array of 84 panels that was only 7 inches thick when folded, but when fully extended, rose more than 10 stories above the Shuttle orbiter cargo bay. In October 1984, a flight test of the Future Identification and Location Experiment demonstrated advanced sensor technology for autonomous classification of Earth's surface features. Use was made of the Shuttle orbiter in 1984 as a test bed for technology and instrumentation for advanced transporation systems.

Space Transportation

Space Transportation System

The achievement of a fully operational Space Transportation System (STS) was advanced substantially in 1984 by new and improved Shuttle operations and developments for the future.

Shuttle Missions. Of the five Shuttle missions in 1984, two were by Discovery (the third vehicle of the orbiter fleet) and three by Challenger (the second vehicle of the fleet). Hardware turnaround time was shortened thereby reducing the time required for Shuttle testing. Progress was made in 1984 toward achieving the goal of a fleet of four operational orbiters by 1985. Another orbiter vehicle, the Atlantis, was added; and the Columbia orbiter transitioned from developmental to operational status. Fourteen major payloads were processed and subsequently launched by the Shuttle in 1984, the highest number in a year to date.

The highly successful in-orbit retrieval, repair, and redeployment of the Solar Maximum Mission satellite by means of the Shuttle in 1984 demonstrated the Shuttle's important capability to service spacecraft and their payloads in space. That capability is to be employed, with significant savings in cost, for future systems such as the Space Telescope, Gamma-Ray Observatory, and the proposed Advanced X-Ray Astrophysics Facility. The Shuttle's retrieval capability also was used during the November 1984 Shuttle mission to recover and return to Earth the Westar IV and Palapa B2 communications satellites that had been placed in unusable orbits because of failure of Payload Assist Modules used in their deployment.

Noteworthy accomplishments in flight operations support of the STS in 1984 were demonstrated in mission planning, mission control, crew training, and production of flight software, as well as in security provisions for the support of DoD classified operations. During 1984, 17 astronaut candidates were selected, the tenth group chosen since the original seven Mercury astronauts in 1959.

Twenty solid rocket boosters (10 flight sets) for the Shuttle were delivered in 1984. The Shuttle's solid rocket boosters performed successfully on all the 1984 launches, and all were retrieved to be refurbished for future use.

Shuttle Payloads. Building on past successes, preparations were underway in 1984 for payloads for future missions. For example, the successful European Space Agency (ESA) Spacelab 1 in 1983 led to a year of transition and preparation for the first operational Spacelab module missions, scheduled for 1985. Originally developed and funded by ESA, Spacelab is an example of continuing international cooperation demonstrated by the Japanese government's 1984 decision to purchase space on a Spacelab module mission in 1988. This followed a decision by the Federal Republic of Germany to fly a series of dedicated missions beginning in 1985.

Other initiatives relating to Shuttle payloads include the development of a Shuttle Payload of Opportunity carrier named Hitchhiker, designed to attract new customers and thus increasing use of space.

Tethered Satellite System. Development of hardware began early in 1984 for the Tethered Satellite System (TSS). A cooperative project of the United States and Italy, the TSS, using the Shuttle orbiter as a base, will provide a means for conducting experiments in the upper atmosphere and ionosphere, regions now not accessible except for very limited periods of time.

Shuttle Upper Stages. NASA continued the design, development, and procurement of the STS/Centaur upper stage for use in the Galileo and Ulysses missions scheduled for 1986. Because the Air Force needs this stage to fulfill certain of its mission requirements, it is sharing in the design and development costs.

Expendable Launch Vehicles

Launch support for 7 NASA missions and 4 DoD missions was provided by expendable launch vehicles (ELVs) in 1984. As noted previously, ELVs are under active consideration for commercial use by private industry, in accordance with the President's policy directive of May 1983. In the meantime, NASA will continue to fulfill launch commitments for these systems through 1987.

Space Tracking and Data Systems

NASA's Space Tracking and Data Systems provided support in 1984 for the tracking, command, telemetry and data acquisition needs of all NASA space flight programs by means of the Space Network, the Deep Space Network, the Spaceflight Tracking and Data Network, and other facilities. A global communications system links tracking sites, control centers, and data processing facilities. The transition to the Space Network from the earlier mode of using a ground network for tracking low-Earth-orbiting spacecraft began in 1983 with the launch of the first Tracking and Data Relay Satellite. In 1984, progress continued toward the ultimate objective of establishing an operational Tracking and Data Relay Satellite System by 1986, permitting many of the existing ground stations to be eliminated.

Space Station

The President directed NASA in January 1984 to develop a permanently manned space station within a decade, and invited the participation of other nations in this endeavor. The objectives: to assure U.S. leadership in space in the 1990s and beyond, to promote international cooperation, to stimulate development of advanced technologies, to enhance capabilities for space science and applications, to encourage private investment in the commercial use of space, and to stimulate interest in education and careers in science and engineering.

Many significant steps were taken in 1984 in response to the President's directive and established objectives. A Space Station program office was established at NASA Headquarters, with responsibility for policy and overall direction; and plans were initiated to acquire, by the early 1990s, an operational space station to be assembled in orbit at an altitude of about 300 miles. A key aspect of the Space Station planning is to be able to incorporate new technology and to adapt to emerging mission requirements, thus enabling the Station to serve usefully in many ways well into the 21st century. Management and engineering guidelines were defined, with the Johnson Space Center designated the "lead center" for Space Station program management and technical implementation. Other NASA Centers were assigned discrete project management responsibilities for different Space Station elements.

International participation is to be a key element of the Space Station Program with funding to be shared with those who choose to participate. Canada, Japan, and the member nations of the European Space Agency are among those who have shown interest in participating. A working group at NASA Headquarters was established to develop guidelines for international participation.

During 1984, the following 3 categories of missions for the Space Station were established: Science and Applications, Commercial, and Technology Development.

In September 1984, NASA issued a Request for Proposal for the definition and preliminary design of the Space Station. Contracts are to be awarded on a competitive basis.

Advanced Development Technology test beds, to be located at various NASA centers, were initiated in 1984 for several purposes, among them to help identify technologies essential for optimum Space Station design and to provide technology options for initial Station capability. As NASA moves forward on Space Station development, participation by the private sector and the international community is expected to grow.

Aeronautics

NASA's aeronautical research and technology activities in 1984 continued to provide the direction and developments necessary for maintaining U.S. preeminence in civil and military aviation.

Simulation. A major goal is to develop an ability to simulate numerically the complex 3-dimensional flow of air around a flight vehicle and thus use small models to test aircraft designs for safety and efficiency, at great savings in time and cost. The Numerical Aerodynamic Simulation program, a response to this goal, will develop the world's most advanced aerodynamic computational facility, capable of such simulation at the rate of one billion operations per second. It will provide a substantial improvement in the efficiency of both the design process and the resulting product.

In 1984, NASA dedicated the Man-Vehicle Simulation Research Facility for use in research and studies to enhance safety, improve flight deck instrumentation and solve other human related problems related to aerospace vehicles. In addition, NASA researchers completed the first half of a crew fatigue and jet lag program by gathering a data base on short-haul commercial air-lines.

Disciplinary R&T. NASA's disciplinary aeronautical research activities are directed at improving understanding of basic physical phenomena and developing new concepts in the areas of fluid and thermal physics, materials and structures, controls and guidance, human factors, and information sciences. In 1984, advances were made in all these areas.

Systems Research. NASA's programs in 1984 on systems research and technology were focused on technologies to improve propulsion, short takeoff/vertical landing (STOVL), advanced turboprop, and supersonic cruise systems. On STOVL, 2 major joint international activities were initiated in 1984: a cooperative program with Canada to test a large-scale ejector STOVL model in NASA's 40 × 80 foot wind tunnel and a planning activity with the United Kingdom to define a cooperative advanced STOVL technology program. Studies continued in 1984 in supersonic cruise technology, with the promise of significant advancement as a result of rapidly evolving gas turbine technology. Progress was made in the advanced turboprop program, including completion of the final design of the large-scale (9-foot diameter) propeller. Work also continued on helicopter technology for public service uses and emergency medical services. This is in coordination with the FAA, Coast Guard, National Highway Traffic Safety Administration, DoD, and segments of the public service and medical community.

Military Support. NASA and DoD conduct many joint programs covering such vehicles as rotorcraft and high performance aircraft. The Automatic Maneuvering Attack System phase of the Advanced Fighter Technology Integration program, an Air Force/NASA effort, began in 1984 and will be completed in 1985. A flight research experiment to develop the technology required for the beneficial interaction of engine and flight controls is part of the NASA/Air Force/industry F-15 Highly Integrated Digital Engine Control activity. A NASA/Navy activity is the development of an oblique wing research aircraft to be designed, fabricated, and tested for operation at transonic and supersonic speeds. The oblique wing concept, conceived by a NASA employee, R. T. Jones, promises potential improvements in performance for a variety of military and civil missions. A Request for Proposal was issued in 1984 for preliminary design of an aircraft embodying this concept. NASA and Air Force test pilots will join in a flight test series to expand the flight envelope of the X-29A Forward Swept Wing Flight Demonstrator, an aircraft incorporating another revolutionary concept. The X-29A program, funded by the Defense Advanced Research Projects Agency (DARPA), achieved several milestones in 1984 including successful high-speed taxi tests. In still another joint program, NASA is managing and supporting, at DARPA's request, a program to develop and flight test the X-Wing Rotor concept on one of the two NASA/Army Rotor Systems Research Aircraft (RSRA). In 1984, the helicopter version of the RSRA was modified to accept the unique X-wing rotor. Other cooperative activities included successful completion of the first full-scale testing and demonstration of concept feasibility of the "convertible" engine and the provision by NASA's research facilities of essential data to the Joint Services Vertical Lift Aircraft program.

Air Safety and Efficiency. NASA has continued to advance technologies to improve aircraft and aviation safety. Among the hazards to which NASA has directed its research are lightning strikes, wind shear, and icing. In a joint activity with FAA, NASA completed development of advanced lightweight, fireworthy materials to reduce the threat of fire in aircraft cabins. In a major research program, a remotely controlled crash of a civil jet transport was conducted successfully at NASA's Dryden Flight Research Facility. The results will assist FAA in implementing additonal safety features for civil transport aircraft.

An activity underway in 1984 investigated extending the concept of automatic flight to the rollout and turnoff phases of aircraft operations for the purpose of reducing runway occupancy times during both normal and adverse weather conditions. This Advanced Transport Operating System will be subjet to additional experiments.

National Aeronautics and Space Administration

Under the National Aeronautics and Space Act of 1958, the National Aeronautics and Space Administration (NASA) is the civilian agency responsible for direction and management of the research and development for all aeronautical and space activities except for those associated with military operations for the defense of the United States, which are under the Department of Defense (DoD). Although NASA and DoD's efforts are separate, there is extensive cooperation. Other federal departments and agencies, state and local and foreign governments as well as educational institutions and industry also share in NASA's programs.

The 1958 Act states that NASA's programs and activities in space, "should be devoted to peaceful purposes for the benefit of all mankind;" and in the discharge of its functions, NASA is to "provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof." The information that follows, as part of the annual Aeronautics and Space Report of the President, is a response to this directive.

Earth Applications

In 1984, applications of space research and development and space technology for use on Earth advanced substantially in various fields, among them communications, environmental observations, agriculture, natural resources, and commercial developments such as materials processing in space for the improvement of medical and industrial products.

Communications

NASA launched its last experimental communication satellite in 1973 and for the next ten years, maintained only a minimum involvement in advanced technology. No new flights were initiated. Subsequently, there have been concerns regarding congestion of the frequency spectrum and geostationary orbital arc, and competition with Europe and Japan in satellite communication technology vis-a-vis Europe and Japan. In 1984, in cooperation with U.S. industry, NASA initiated a vigorous program to develop the advanced high risk spectrum and orbit efficient technology needed to ensure continued growth of this important industry and to maintain U.S. preeminence in the world marketplace.

Advanced Communications Technology Satellite (ACTS). Working with a wide segment of U.S. industry, NASA will develop the world's most advanced communication technology satellite, ACTS, to be launched and ready for experiments in 1989. ACTS will allow large numbers of U.S. companies, universities, and government agencies to experiment with spot beams, hopping beams, and switchboard in-the-sky concepts that ultimately will enter the market place by the mid-1990's.

Mobile Satellite. Satellite-aided communications from cars, trains, buses, and other mobile platforms has been one of the unfilled promises of modern technology. A system of this type would augment planned terrestrial service in non-metropolitan areas of the U.S. and thus provide a truly ubiquitous, nationwide network. Applications include emergency response communications such as wide area law enforcement, national disaster assessment, and emergency medical service as well as numerous business and commercial uses such as communications for interstate trucking and remote oil and gas well drilling operations.

In 1984, through a multiple set of joint endeavor agreements with U.S. industry and a cooperative agreement with Canada, NASA initiated a three-phase program that will help industry provide commercial mobile communications in the late 1980's. This program is in direct response to the President's commercialization of space policy and will develop new hardware markets, businesses, and service industries. NASA's involvement will be primarily in the development of technologies needed to conserve power and the frequency spectrum/orbit resource so important to the future growth and economic viability of the system. Important examples of this technology include higher gain vehicle rooftop antennas and multibeam spacecraft antennas that can reuse the allotted frequencies many times. In addition, NASA is working with other government agencies toward an experimental program that would help those agencies determine the usefulness of mobile satellite service for their operations.

Search and Rescue. During 1984, the COSPAS/SARSAT system successfully completed its demonstration and evaluation phase and began an era of regular operation. This international cooperative program has demonstrated the use of satellite technology to detect and locate aircraft and vessels in distress. This technical performance of the combined satellite and ground system has equalled or exceeded expectations of sensitivity, accuracy, and ground coverage. Even more impressive has been the use of the system in real distress operations resulting in the saving of 289 human lives throughout the world. The system enjoys wide international participation which has resulted in reduced system costs and broad sharing of the benefits. The United States, Canada, France, and the Soviet Union developed the system; and Norway, the United Kingdom, Sweden, Finland, Bulgaria, Denmark, and Brazil also are participating.

Its success was affirmed when all of the nations which participated in its development signed a new Memorandum of Understanding in October 1984 to enter into a new period of initial operational use of the system.

Optical Intersatellite Links and Other Component Techniques. NASA continues a broad based advanced research and development program in communications component technology. Solid state and electron device amplifiers, and monolithic receivers and amplifiers are being developed for frequencies through 60 GHz. A major effort continued in 1984 to develop laser communications for intersatellite links between geosynchronous and low earth orbiting spacecraft and for deep space communications.

Environmental Observations

New and more advanced instrumentation, particularly more complex sensors, provide a bonus of more detailed information and consequently greater understanding of earth's environment and the processes that affect it.

Upper Atmosphere. Work began on the observatory and ground data handling segments of the Upper Atmosphere Research Satellite (UARS) program. Instrument development for the scientific payload of UARS had begun in 1982, in recognition of the fact that development of the complex, remote-sensing instruments is the pacing task in the implementation of the UARS program. The UARS, scheduled for launch in late 1989, will be the first satellite capable of simultaneous measurements of the energy input, chemical composition, and dynamics of the stratosphere and mesosphere. A critical component of NASA's program is to understand the upper atmosphere well enough to assess its susceptibility to chemical change. When fully implemented, the program will provide the first global-scale data set for scientific study of the coupling of chemical composition and dynamics driven by solar energy input, which is the striking difference between the upper atmosphere and the lower atmosphere and which largely determines the behavior of the stratosphere.

In 1984, NASA completed the first phase of the Global Tropospheric Experiment/Chemical Instrumentation Test and Evaluation (GTE/CITE) Project, a research-aircraft-based effort to validate, through intercomparison, the extremely sensitive instruments that will be needed to study global tropospheric chemistry. The overall objective of GTE is to assess the role of the troposphere as the ultimate source and sink for chemical species in the stratosphere, the contribution of tropospheric ozone to total ozone content of the atmosphere, and the role of tropospheric chemistry in biogeochemical cycles. Future phases of GTE will continue the critical instrument development and testing, evaluate source strengths of biogenic gases in a variety of environments, study boundary layer/free tropopause exchange rates, probe stratosphere/troposphere exchange processes, and evaluate the role of various chemical and dynamic processes in controlling atmospheric concentration distribution.

In January 1984, NASA reported to the Congress and the Environmental Protection Agency on the current status of stratospheric research, as required by provisions of the Clean Air Act Amendments of 1977. Several key issues with regard to the stability of the ozone layer were identified. In particular, concern remains that anthropogenic effects may alter the concentration of stratospheric ozone. Moreover, it now is well recognized that the magnitude of such effects depends critically on the future concentrations of atmospheric trace gases such as methane, nitrous oxide, carbon dioxide, and oxides of nitrogen. Theoretical models, based on the best chemical laboratory data available, show that nitrogen oxides are especially significant in controlling the onset of strong, non-linear perturbations of ozone by chlorine compounds derived from chlorofluorocarbons. As a result of these findings, increased emphasis in the program is being placed on the measurement of trace gas concentrations and on the development of means to predict their future behavior.

Improved strategies have been formulated for monitoring changes in the concentration and distribution of stratospheric ozone for the calibration of satellite ozone sensors which monitor ozone globally.

As a step towards understanding the mechanisms by which trace species are exchanged between the troposphere and the stratosphere, a major aircraft measurement program to study atmospheric transfer processes has been initiated. Plans call for five major missions using the NASA U-2 and ER-2 high altitude aircraft in the extratropics, the subtropics, and the equatorial region in the years 1984-1987.

Geodynamics. The first direct measurements of the movement of the tectonic plates that make up the crust of the earth have been obtained by the NASA Geodynamics Program, using laser ranging to special satellites such as the Laser Geodynamics Satellite (Lageos), and using very long baseline microwave interferometry (VLBI), a technique pioneered by radio astronomers. These measurements constitute a key test of the plate tectonics theory which has revolutionized the earth sciences in the same way that quantum mechanics and relativity revolutionized physics nearly a century ago.

The new data, acquired using space methods, show, for example, that North America is moving away from Europe at a rate of 1.3 centimeters per year; and this and the observed relative motion of other pairs of plates are in good agreement with the predictions based on the geological record, averaged over millions of years. Continuation of these observations for longer times should result in information on how the dynamics of the earth's interior affect the rate of motion of the plates.

Satellite laser ranging measurements of the relative motion of the North American and Pacific plates between two points along their boundary (the San Andreas Fault System in California) 800 kilometers apart, have been refined; and the relative motion is now well established at 6.5 centimeters per year—substantially higher than rates of deformation observed by ground measurements close to the San Andreas Fault. These observations have led to the conclusion that a significant portion of the relative motion of these two plates must be taken up by movements along other faults, either on land or under the sea, west of the San Andreas Fault. The space observation program is continuing to gather data on deformation of the two plates in the vicinity of the San Andreas Fault, highly relevant to the Earthquake Hazard Reduciton Program being carried out by the U.S. Geological Survey. NASA and the USGS are cooperating in a joint research program to mitigate the hazards of earthquakes to life and property in California.

Laser ranging to the Lageos satellites has detected, for the first time, a change in the gravity field of the Earth. This change apparently is related to the slow rising of the Earth's crust in North America and Scandinavia, which has been occurring at the rate of a few millimeters per year since the recessions of the glaciers which covered these areas 18,000 years ago.

NASA continues to cooperate with other countries in geodynamics programs, through coordination of observatory measurements and through cooperation in the deployment of mobile laser ranging and VLBI stations to measure crustal deformation in areas of the world where significant earthquake hazards exist. In addition to the Western United States, these measurements will be made in the Mediterranean and Near East, in South America, the Caribbean, and in Western Canada.

Land Observations. The development, testing, and evaluation of sensor systems to discriminate surface materials by measuring reflected or emitted radiation continued during 1984. During the year, Landsat-5 was launched; and an "Announcement of Opportunity" was issued to solicit and fund research in the earth sciences utilizing the improved spatial and spectral capabilities of the Thematic Mapper (TM) flown on Landsats 4 and 5. This science assessment of the TM is a companion to the engineering/data quality assessment completed in 1984.

The STS-17 mission, launched October 5, 1984, carried two major land remote sensing experiments: the Shuttle Imaging Radar (SIR-B), a reflight of the L-Band instrument flown originally as SIR-A but with multiple incidence angle capability which permits improved discrimination of surface terrain features; and the Large Format Camera (LFC) which will produce high resolution stereo photography, essential in constructing accurate base maps for scientific studies.

Aircraft instrument development during the year included a new radar capable of producing either L or C-Band near-simultaneous multi-polarized data for a given site. This data, used to classify an area in South Carolina, permitted the separation of Hardwood Islands from marsh on tributary Deltas, which was not possible with single polarization data.

Monthly global vegetation maps, based on the "Advanced Very High Resolution Radiometer" sensor flown on the NOAA series of polar orbiting satellites, were used to study the interaction of the land surface with the atmosphere. During 1984, the metabolic activity of the global vegetation was successfully linked to the annual variation in atmospheric CO_2 levels.

A major new international research project, International Satellite Land Surface Climatology Project, was launched under the auspices of COSPAR and the International Association of Meteorology and Atmospheric Physics. The first objective is to conduct a retrospective analysis of existing remote sensing data to determine to what extent changes in the land surface climatology can be measured and to assess the importance of various processes. The second is to validate current satellite-based information on scales up to 400 km^2.

Operational Meteorological Satellites. NOAA-F was launched into a sun-synchronous orbit on November 8, 1984. Upon achieving orbit, NOAA-F was redesignated NOAA-9 and replaced NOAA-7 as NOAA's operational afternoon (2:30 p.m. local time) spacecraft. NOAA-9 is be the second of the advanced TIROS-N spacecraft. These spacecraft are a "stretched" version of the original TIROS-N series and provide expanded capabilities to handle additional operational and R&D instruments. NOAA-9 is the first operational spacecraft to carry the Solar Backscatter Ultraviolet radiometers to provide global measurements of atmospheric ozone concentration for both NASA research and NOAA operational objectives. NOAA-9 also will carry Earth Radiation Budget instruments intended to fly in conjunction with NASA's dedicated Earth Radiation Budget Satellite (ERBS). These instruments measure the Earth's radiation balance between incoming and outgoing energy. Data from both these instruments will be used in support of climate research activities. The Search and Rescue instruments to be flown on NOAA-9 are a continuation extension of those successfully tested on NOAA-8. This international system detects and locates distress signals from ships and aircraft and already has been credited with saving over 280 lives.

Precise measurements of the color of the ocean can be used to map the distribution of marine phytoplankton from satellites. These microscopic marine plants provide the basis for marine food webs and perform about half of the total global photosynthesis. On a global scale, such information would provide a previously unobtainable description of ocean biological productivity. This novel view would expand our understanding of carbon and nitrogen fluxes in the ocean, as well as provide information directly relevant to the management of fisheries. In 1984, NASA initiated a Phase A study to determine the feasibility of flying an Ocean Color Instrument on the French SPOT-3 spacecraft. This instrument is an improved version of the Coastal Zone Color Scanner which was flown successfully on NASA's Nimbus-7 research satellites. The new instrument would provide global data sets and eventually could be incorporated by NOAA as an addition to their complement of operational environmental instruments.

Climate

Climate Research. A major step was taken with the launch of the Earth Radiation Budget Satellite (ERBS) on October 5, 1984, carried into orbit by the Space Shuttle Challenger. ERBS is the first of a three satellite system designed to carry broad band radiometers to measure the components of the radiation balance which exists between the sun, Earth, and space. The other two satellites are the NOAA F and G operational meteorological satellites to be launched in November 1984 and in early 1986, respectively. Together, these comprise the Earth Radiation Budget Experiment (ERBE), the centerpiece of the NASA climate observing system.

In a related area, it is well known that the lack of understanding of important physical processes governing the interaction of clouds and radiation constitutes a serious obstacle to improved climate modeling and prediction. In recognition of this problem, the World Meteorological Organization (WMO) and International Council of Scientific Unions (ICSU) are jointly sponsoring an International Satellite Cloud Climatology Project (ISCCP), whose goal is to exploit the international array of operational meteorological satellites in establishing a 5-year data set describing the properties of the global cloud cover. NASA is a key participant in this activity as host to the project's Global Processing Center which is responsible for merging and analyzing the vast amounts of cloud imagery (from 6 satellites) and producing a final cloud climatology for further research.

In September 1984, with the concurrence of the National Climate Program Policy Board, NASA established the National Project Office for the First ISCCP Regional Experiment (FIRE), in cooperation with NOAA, NSF, and DOE. The objectives of FIRE are to promote coordinated studies of cloud-radiation processes leading to an improvement in the way that clouds are treated in climate models. FIRE also will contribute to the validation of ISCCP in conjunction with similar efforts to be supported by Japan and other countries. A university /government science team has been selected; and planning is underway with initial emphasis on the study of cirrus clouds. Although not well understood, cirrus clouds are of great importance in the transfer of infrared radiation in the atmosphere. It is expected that both ISCCP and FIRE results also will aid in the interpretation of ERBE measurements.

Global Scale Atmospheric Processes. Advanced techniques for satellite observations of the Earth's atmosphere are being developed using laser radars. These laser techniques are tested from aircraft platforms to observe a number of atmospheric parameters which include temperature, pressure and humidity profiles. Additionally, techniques have been developed to utilize coherent laser radars to observe global wind profiles. Computer models of the large-scale motions of the Earth's atmosphere have been used to guide the development of these future satellite sensors. Model studies show that satellite observations of global wind profiles will improve dramatically our understanding of large scale atmospheric processes. This improved understanding enhances the ability to predict weather processes.

Techniques also have been developed which use satellite radar data to determine wind speed and direction at the ocean surface. Fifteen days of satellite data have been processed to show the usefulness of these surface wind determinations. Large scale wind features, independently predicted to exist in the tropical oceans, subsequently were identified in the fifteen day data set.

Mesoscale Research. The basic research program at NASA dealing with questions of atmospheric behavior leading to severe weather is called the Mesoscale Atmospheric Processes Research Program. Uses of high-altitude and space-derived data are developed for analysis with conventional weather observations to obtain new perspectives and interpretations of atmospheric behavior, especially in regions of the world where ordinary observations are scarce. In 1984, several special studies were conducted of small, high-velocity downdrafts called microbursts, to help increase airline safety by improving pilots' understanding. A new sending capability, the airborne Doppler lidar, mapped wind fields in the clear air over the Pacific marine boundary layer, the California Central Valley circulation, air flow entering storms, and intercompared its observations with the new ground-based very high frequency (VHF) wind profilers at Penn State University. Special missions of high-altitude aircraft with remote sensors for temperature moisture, electric field variations, lightning spectral emissions, and precipitation were flown over storms to provide more insight for numerical studies to unlock internal storm processes.

Several efforts were directed at improving mesoscale numerical models to include varying input data, land surface effects, improved handling of cumulus cloud effects, storm triggering factors; and initial work was begun on a new class of models with interactive scales of behavior, including feedback mechanisms.

Emphasis was placed on new computer display techniques involving three and four dimensional presentations to help interpret hurricane evolution and growth mechanisms, squall line development, and storm initiation. Further development of these techniques in furure years will be designed to allow visual interpretation of complicated numerical model outputs.

Much initial work was conducted to prepare for several coordinated interagency field measurement programs to occur in 1986 as well as plan for advanced U-2 sensors, a series of Space Shuttle remote sensor pallet flights and a geostationary research satellite that will extend the mesoscale satellite observables to precipitation, lighting and ozone, plus detailed vertical profiles of temperature and water vapor.

Oceanic Processes. During 1984 the "Oceanography from Space, Research Strategy for the Decade: 1985-1995" was published. In concert with this strategy, (1) FY-85 budget approval has been obtained for the NASA Scatterometer (NSCAT) and the Navy Remote Ocean Sensing System (NROSS) satellite, on which NSCAT will fly; (2) a joint NASA/French Space Agency (CNES) study has been completed looking at the detailed definition of a cooperative scientific mission in satellite altimetry, the NASA component being the proposed Ocean Topography Experiment (TOPEX); and (3) definition and accommodation studies are underway for the flight of the proposed Ocean Color Imager (OCI), an improved version of the Nimbus-7 Costal Zone Scanner, aboard either NOAA-K or SPOT-3. If flown, these spaceflight activities—NSCAT, TOPEX, and OCI—will permit global observations of atmospheric wind forcing, ocean current response, and associated phytoplankton productivity, respectively. As such, they are key elements of the World Climate Research Program (WCRP), proposed for initiation in 1989/1990. Simultaneous observations from these three activities will permit, for the first time, an assessment of the interdependence of atmospheric and oceanic variability, and its collective influence on the Earth's climate.

Science

During 1984, investigation of the physical nature of the universe and our solar system continued with important new findings in astrophysics. Cometary studies received special emphasis in preparation for observations of the comets Giacobini-Zinner (1985) and Halley (1986).

Solar System Exploration

Observations of the interplanetary medium in the outer solar system continued in 1984 with four active planetary spacecraft, Pioneers 10 and 11 and Voyagers 1 and 2. Pioneer 10 returned data on the interstellar medium at a distance of nearly 35 astronomical units (AU) from the sun. This is well beyond the orbit of Neptune and in the direction opposite to the solar apex, which is the direction of the sun's motion with respect to nearby stars. Pioneer 11 obtained similar data but in the direction of the solar apex and at a distance of only 17 AU, well inside the orbit of Uranus. Additional observations of the interplanetary medium are being returned from the two Voyager spacecraft, both still inside the orbit of Uranus. Voyager 2 is approaching its January 1986 encounter with Uranus.

Study of the inner solar system is continuing with the fifth year of the Pioneer Venus Orbiter mission. This mission is still in its increasing periapsis altitude phase which started in 1980. The periapsis (the lowest altitude above Venus of the spacecraft orbit), will increase from a low of 200 km in 1980 to a maximum of 7300 km in 1986 and then will decrease until the spacecraft enters the Venus atmosphere in 1992. Among other scientific objectives, the high altitude phase of the Pioneer Venus mission permits in-situ sampling of the interaction between the solar wind and the Venusian ionosphere.

Final testing of the Galileo spacecraft in 1984 was in preparation for its May 1986 mission to Jupiter. Two newly approved planetary missions are in the development phase. The Venus Radar Mapper will be launched in 1988 for extended mapping of the cloud covered surface of Venus, and the Mars Geoscience Climatology Observer will be launched in 1990 to study that planet's climate and soil-atmosphere interaction over a full Martian year of nearly 700 earth days.

Cometry studies play a prominent role in the program. Following a close flyby of the moon in December 1983, the International Cometary Explorer

(ICE) spacecraft is now headed toward a September 1985 encounter with the comet Giacobini-Zinner where it is targeted to pass through the comet's tail. Preparations also are underway for observations of Comet Halley during its 1985-1986 apparition. American scientists will observe the comet using the Shuttle Astro-1 payload in March 1986 as well as participating as co-investigators on the European Space Agency's GIOTTO and the USSR's VEGA missions which also will encounter the comet during March 1986. Observations of Halley near the time of its close approach to the sun also will be made from the Pioneer Venus Orbiter and a Spartan spacecraft launched and retrieved by the Shuttle.

Study of The Universe.

The NASA Astrophysics Program investigates the physical nature of the universe, from our own sun outward to the most distant quasars to determine the laws that govern cosmic phenomena, to understand the sun as a star, and to learn how the universe began and how it will end. Many observations cannot be made through the Earth's atmosphere, and so instruments for such observations must be carried above the atmosphere into space.

High Energy Astronomy Observatories. During 1984, the High Energy Astronomy Observatories (HEAOs) have continued to provide significant new results on a wide range of astrophysical phenomena. Mission objectives were completed, and analysis of the great storehouse of data from the HEAOs continues to bring us new and exciting information about the most chaotic and energetic processes occurring in the universe. A particularly significant finding from the HEAO data is in the area of explosive nucleosynthesis in our Milky Way Galaxy. Through the observation of a galactic "ridge" of gamma rays emitted by excited aluminum-26 nuclei, the High Resolution Gamma Ray Spectrometer on HEAO-3 has yielded, firm evidence of the recent processing of heavy nuclei in stars. This isotope must have been synthesized in the recent past as its radioactive lifetime is only a million years, a short time scale compared to the ages of stars and of the Milky Way. HEAO-2 data also had yielded a significant new result; a spectrum of the *BL Lacerta* object designated PKS* 2155-304 revealed a sharp absorption feature attributed to ionized oxygen in the line of sight to the object.

Gamma Ray Observatories. BL Lacerta objects are thought to be one variety of quasar and will be primary objects of study for the instruments on the Gamma Ray Observatory (GRO). In 1984, the critical design reviews were completed on all the instruments; and fabrication and assembly was begun for flight instrument hardware. Also in 1984, the preliminary design review of the spacecraft was completed. GRO is proceeding toward its launch in 1988.

Two mission specialists, Astronaut George D. Nelson right, and James D. van Hoften, left, participants of Flight 41-C, repairing the recovered Solar Maximum Mission Satellite in the aft end of the Challenger's cargo bay. Both use the mobile foot restraint and the remote manipulator system (RMS) for moving about. After repair, the RMS lifted the satellite into space once more.

Solar Maximum Mission. 1984 saw the first use of the new technology for repairing spacecraft in orbit with the repair of the Solar Maximum Mission (SMM) by the Space Shuttle. During the rest of 1984, most SMM instruments have functioned normally. Improvements derived from the repair mission have made possible some new and revealing observations of the structure and dynamics of solar prominences. With the repair of the Coronagraph/Polarimeter, observation of the global structure of the solar corona has commenced. This is especially important because it will allow comparison with results from Skylab. If SMM had not been repaired, such comparison would be impossible until 1995. One of the most profound and significant results is derived from analysis of all 4 years of SMM solar flare data and the discovery of a 155 day period in the occurrence of outbreaks of solar flares. This specific amount of time implies that the magnetic phenomenon that drives solar flares comes from deep within the Sun and not from within the surface as had been previously thought.

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*PKS - an astronomically derived term, not an acronym

Explorers. Perhaps the most dramatic increase in astrophysical knowledge in 1984 has come from the continued analysis of data from the Infrared Astronomical Satellite (IRAS) launched in January 1983. IRAS surveyed the sky in the wavelength range from 8 to 120 microns, and a catolog of more than 200,000 entries was issued in November 1984. More than 98 percent of the sky was covered at least twice, and each object in the catalog has an extremely high probability of being a true source. This high degree of completeness and reliability makes the catalog especially valuable. Previous catalogs of infrared sources have had only 1,000 objects.

In August 16, 1984, three Active Magnetospheric Particle Tracer Explorers—the Ion Release Module (IRM), the UK Subsatellite (UKS), and the Charge Composition Explorer (CCE)—were launched. The IRM injects tracer atoms at an altitude near 113,000 km above the Earth while the UKS observes conditions at the time of release from within a few hunderd kilometers of the IRM. As these atoms are ionized and carried in the solar wind to the Earth's magnetosphere, the CCE detects their arrival in the Earth's magnetosphere. This collaborative mission is sponsored jointly by the Federal Republic of Germany which developed the IRM, the United Kingdom which developed the UKS, and the United States which developed the CCE and provided the launch.

Development of the Cosmic Background Explorer (COBE) continued in 1984. The most significant event was the successful leak test of the cryogen tank for the liquid helium dewar. COBE will survey the cosmic background radiation left over from the Big Bang. The Extreme Ultraviolet Explorer was approved as a mission in 1984. Instrument development began during 1984; and launch is planned for the end of 1988.

Suborbital Observations. 1984 was a very significant year for each of the four elements of NASA's suborbital program: Spartan, Balloons, Rockets, and the Kuiper Airborne Observatory (KAO). The first Spartan carrier and its instrument were readied for flight in 1984 and were manifested on Discovery's August 1984 flight. It was necessary to reschedule this flight for 1985. An additional Spartan mission has been added to observe Comet Halley in January 1986. The carrier for the Halley mission and the third carrier are under development. A significant balloon campaign to Australia was conducted in October and November of 1984 to carry high resolution gamma ray telescopes above the atmosphere and observe the annihilation of antielectrons in the center of our galaxy. For Fiscal Year (FY) 1984, there were 35 successful balloon flights.

A major compaign to study plasma physics in space with sounding rockets was begun in Greenland in December of 1984 and will continue through February 1985. A total of seven launches will be attempted. In FY 1984, 38 successful rocket launches were made as well as 64 missions of the KAO with 511 hours of flight time. The KAO carries a one-meter telescope for infrared and submillimeter observations above the absorbing water vapor in the Earth's atmosphere. From August through the middle of October 1984, the KAO underwent a major overhaul in its Periodic Depot Maintenance.

Advanced Technology Development and Long-Range Planning. Phase B for the proposed Advanced X-Ray Astrophysics Facility (AXAF) began in July 1984. Proposals for scientific instrument development were received and reviewed in 1984, with the selection to be announced at the beginning of 1985. Also in 1984, mirror technology demonstration programs were continued with the Perkin-Elmer Corporation and the Itek Corporation with X-ray mirrors to be delivered in 1985. In 1984, the decision was made to investigate an engineering test of the proposed Gravity Probe-B (GP-B) instrument for flight on the Space Shuttle in 1988. Proposals were received from corporations to design and fabricate the engineering test model. This may lead to a scientific flight mission in polar orbit in 1992.

Investigators for the proposed Space Infrared Telescope Facility (SIRTF) were selected in 1984. During the year, redefinition of the mission as a free-flyer or as a platform mission in the Space Station system has continued. Studies also were begun on resupplying superfluid helium to this mission from the Space Station to extend the mission lifetime up to a decade. This will be the first significant increase in our understanding of infrared sources since the IRAS mission. Design work for the Solar Optical Telescope (SOT) also was continued in 1984.

Hubble Space Telescope. The Hubble Space Telescope, a major astronomical observatory, is the first space facility designed and built from inception to be serviceable on orbit by the Shuttle Orbiter. Operating beyond atmospheric influence, it will be capable of observing objects 50 times fainter and 7 times farther than can be done from the largest ground-based telescopes. All science instruments and the structural, optical, and electronic components have been fabricated and tested. Major subsystem integration began in late 1984 and operational verification tests will begin early in 1985. The Hubble Space Telescope is on schedule for launch in the second half of 1986. Expectations are that science instrument upgrades on orbit can begin approximately five years after launch, enabling the science community to take advantage of advances in instrument technology as well as to replace degraded or failed instruments. With the advent of the space station, it is likely that more comprehensive on-orbit servicing will be possible, thereby obviating the necessity to ever return the Hubble Space Telescope to Earth for refurbishment.

Life Sciences

Studies continued on the monitoring and maintenance of human passengers in space as well as with medical concerns of short-term missions. Human adaptation to the gravity-free space environment received attention; and investigation continued with respect to treatment of space sickness. Space biology and the study of plant growth and development in space received attention as well as global biology research.

Space Medicine. In 1984, as in previous years, the Space Medicine Program, was concerned with the health and safety of spacecraft crews. Primary emphasis continued to be placed on operations of the Space Shuttle, on the refinement of medical standards, on the medical selection of crews, on their medical training, and on the monitoring and maintenance of their health and career longevity.

Health trend data, acquired from the astronaut population in the course of regularly scheduled physical examinations, were compared with similar measurements made immediately preflight, postflight and, in certain instances, inflight. For the most part, the health of Shuttle crews remained excellent; and no evidence has been obtained to suggest that impairments in human physiology or performance will limit the usefulness of either the Space Shuttle or of the forthcoming Space Station.

Particular attention was directed toward the incidence of the signs and symptoms of the Space Adaptation Syndrome (SAS) and the efficacy of currently available therapeutic techniques. Several drugs have proven useful in treating motion sickness inflight; and water-salt replenishment procedures have been used successfully to partially prevent the development of untoward cardiovascular responses following reentry.

In addition to this program in the Space Shuttle, medical research continued with respect to the medical concerns of both short-term and long term missions. At the Space Biomedical Research Institute, established last year at the Johnson Space Center, research on the SAS problem has progressed. Data have been acquired which document for the first time some of the changes in perception that have been reported by both Soviet and American crews. As a result of ground-based research, several new drugs have been shown to be promising candidates for inflight testing as remedies for motion sickness. New inflight data on cardiovascular dynamics have been obtained and have indicated that certain changes, e.g. in heart volume, have persisted for several days to a week postflight. There is now a search for procedures to prevent these changes and to facilitate the readaptation process.

Elsewhere in NASA and among its academic grantees and industrial contractors, progress was made in understanding the neurophysiological basis of motion sickness and in identifying various physiological and chemical clues that might be useful in predicting who will be responsive to provocative inflight stimuli. Research has advanced knowledge of neuromuscular physiology particularly the understanding of the biochemical changes that occur when muscles atrophy. New remedies have been sought for the bone changes that occur in space as well as those that occur among the elderly on earth; and significant steps have been taken in the development of a Computer Tomography (CT) scanner able to detect small but highly meaningful changes occurring deep within the bones of the spine. Among other fields of intense research interest is the area of radiobiology. In addition to the continued monitoring of astronaut radiation exposures, investigations have taken place into the hitherto unknown effects of high energy cosmic rays on living organisms. In part as a result of work this work, carried out using a ground-based accelerator, radiation standards applied to Space Station crews undoubtedly will become more conservative.

Space Biology. Ground based and Spacelab-1 flight experiments with plants have added significantly to our knowledge of plant growth control mechanisms. In a spaceflight experiment, a phenomenon of continuous circular oscillation exhibited by all plant shoot tips was proved to be gravity independent, thus settling a scientific question debated since the time of Charles Darwin. Ground research found that a complex biochemical mechanism including calcium movement, an ion gradient, and a plant hormone (auxin) is involved in the transfer and translation of a gravitational stimulation of a plant into a growth response. Further, both gravity and light play an integrated role in controlling plant growth. The exact mechanism of this control now is under investigation. These studies are providing the foundation for the future cultivation of plants in life support systems in space.

In 1984, ground-based animal experiments in the Space Biology Program provided significant information in understanding the vestibular, skeletal, and muscular systems of animals. Experimental data have helped in understanding: (1) how the nervous system perceives and transmits orientation, acceleration and gravitational information—this research indicates that the nervous system functions similar to a computer; (2) the concept that bone growth and maturation have a gravity component; and (3) that properties of skeletal muscles are strongly dependent on pattern and level of load-bearing and motor unit activity.

U.S. investigators are analyzing postflight data from the U.S.S.R. Cosmos 1514 biosatellite, flown December 14-20, 1983. This is expected to yield important information about the effects of spaceflight on fetal and postnatal development of rats. In 1985, Spacelab-2 will carry a plant experiment to explore the effects of weightlessness on the formation of lignin, a prime structural component of plants.

Preparations continued during 1983-1984 for 5 experiments dedicated on Spacelab-4 to the fundamental problems of Space Biology. These experiments include: (1) observation of inflight fertilization and early development of frog eggs; (2) the determination of the time course and alterations of calcium metabolism in young rats in space; (3) thermoregulation in primates in the space environment; and (4) two plant experiments—one on gravitropism, the other on phototropism.

Life in the Universe. Studies continued in 1984 on the origin, evolution and distribution of life, and life-related chemicals, on Earth and throughout the universe. Recent discoveries in meteorites of molecules, which are precursors to the genetic material of cells, has significantly broadened our views of the universality of the chemistry of life. Laboratory simulation experiments have demonstrated the synthesis of other biologically important molecules which previously had been inferred from spacecraft observations to be present in atmospheres of the outer planets. Examination of ancient terrestrial rock samples has revealed the presence of primitive life forms in samples as old as 3.5 billion years. These same samples also are providing information on characteristics of the environment (i.e., temperature, atmospheric composition, etc.) in which life arose. Such findings not only will describe the sequence of events of this planet, but also will assist in evaluating the probability of similar event occurring on other planets.

Biospheric Research. The Biospheric Research program, formerly Global Biology, investigates the influence of biological processes on global biogeochemical cycles. Studies of biogenic gas emissions over the ocean and from selected ecosystems confirmed the large scale influence of biologically mediated proceses on atmospheric composition and dynamics. The assessment of the overall effect of deforestation, land use practices and changes, and other natural and anthropogenic perturbations is directly related to the characterization of representative global ecosystem functions. Selected regions and ecosystems are studied with the intent of correlating specific ecosystem parameters with remote sensing data in order to extend those specific regional or habitat functions spatially. Mathematical models are used to integrate field measurements, large scale remote sensing observations, and other ancillary data. Accurate projections of the state of the biosphere and possible perturbation effects will develop by updating the data and refinement of the models.

In addition to individual research tasks to develop new techniques, modeling, and field measurements and methodologies, the following specific field projects were initiated in 1984 to define ecosystem behavior and function:

1) Eastern Coastal Wetlands project—the characterization of key biogenic gas emissions, nutrient transport mechanisms, and biomass estimates combined with remotely sensed data to assess the wetland biogeochemical processes and large scale influences;

2) Sequoia National Park project—in cooperation with the Park Service, the characterization of boreal forest biogeochemical cycling combined and correlated with remote sensing data for comparisons of other representative regions of the boreal forest. Other projects and missions will be initiated to provide new and important data on large scale biogeochemical cycling as well as updating existing data;

3) Amazon Basin Gas Emission Study—discussions have been initiated for the necessary planning and preparations to measure important biogenic gas emissions from the Amazon for both the development of aircraft concentration correlation techniques to ground emission measurements and initial investigations of large scale tropical biogeochemical cycling.

Spacelab Flight Program

Data analysis and results from the successful Spacelab 1 mission are now in print. Over 50 publications in scientific journals have resulted from analysis of mission data. The July 1984 issue of *Science* magazine reported those results which included more complete information on the vestibular changes that occurred in flight and immediately post flight. These will be used by the scientific community to plan more experiments to explore the biomedical changes that occur during and after spaceflight for future missions.

In August 1984, the OSTA-1 mission on Spacelab demonstrated deployment and retraction of large structures that could be used in the future for light weight solar arrays. During the mission, the dynamics of the structures were tested.

During the OSTA-3 mission in October 1984, the SIR-B radar and Large Format Camera returned outstanding images of selected test sites around the world. Two other instruments on this mission were flown originally on OSTA-1 in 1981. The experiment, Mapping of Air Pollution from Satellites, measured global distribution of carbon monoxide in the atmosphere. The Feature Identification and Location Experiment demonstrated the capability to discriminate between cloud cover, water, vegetation, and bare ground. On future missions, this will permit mapping instruments to be automatically turned off when cloud cover prevents observations of the Earth's surface.

Final preparations are now underway at the Kennedy Space Center to complete 3 integration and test activities for a January 1985 launch.

Flight hardware for the first Space Life Sciences 1 mission was delivered in 1984 to the respective development Centers for hardware/experiment verification and science verification tests.

Space Transportation

Space Shuttle

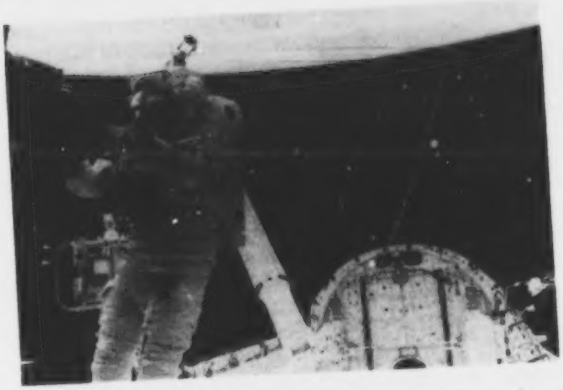
Work on the Space Shuttle in 1984 included development of vehicle operational capability, Kennedy Space Center (KSC) flight and ground support, Vandenberg Air Force Base (VAFB) activation support, Filament Wound Case Solid rocket Booster (SRB) integration, and Shuttle/Centaur integration. Some items specifically considered were methods for verifying flight systems interfaces and operation, Shuttle characteristics encountered during various flight phases, optimum trajectory design, various element hazard analyses, avionics and software testing and design reviews, weather/environmental and earthquake effects, and logistics implementation.

In 1984, a decision was made to augment customer services during 1985. For this purpose, a marketing contractor from the private sector will assist NASA in acquiring new and larger market shares for the Space Shuttle from the growing world demand for space launch services.

The Office of Space Flight (OSF) at NASA Headquarters and its associated field centers (Kennedy Space Center, Marshall Space Flight Center, Johnson Space Center, National Space Technology Laboratories) increased information management activities during 1984. Several automated systems exist, and others continued to be established. OSF installed a network of work stations sharing a common data base of managerial and budgetary information. This makes it possible for all levels of management to share, manipulate, and transfer information. Additionally, OSF began an extensive plan to exchange data electronically with its associated centers; and by the end of 1985, OSF expects to have established total communication capability with systems at all of its centers. Shared data bases and electronic data transfer will enable all levels and locations of the Space Transportation staff to process information expeditiously for decision making and to obtain up-to-date status reports on their projects immediately. This ability became an essential managerial operating tool during 1984 and will continue to be enhanced during 1985.

Space Shuttle Missions

In April 1984, the Solar Maximum Repair Mission demonstrated the capability of the United States Space Shuttle to retrieve, repair in-orbit, checkout, and redeploy operational spacecraft that have experienced debilitating failures. The highly successful in-orbit repair of the Solar Maximum Mission satellite demonstrated another important capability of the STS, that of "in space" payload processing. This capability will be exploited in the future on such missions as the Space Telescope, Gamma-Ray Observatory, the proposed Advanced X-Ray Astrophysics Facility, and other orbiting observatories, with significant cost savings over the life-cycle of these important programs. The repair mission was conducted in concert with the deployment of the Long Duration Exposure Facility, a payload itself scheduled to be retrieved within a year from launch.



Astronaut James D. van Hoften, mission specialist, using a special tool to work on a faulty attitude control of the Solar Maximum Mission Satellite (SMMS) recovered for repair on the 41-C Earth-orbiting Challenger. In the aft section of the Challenger, the astronaut is anchored to a "cherry picker" device which involves a foot restraint/work station connected to the remote manipulator system (RMS).

A malfunction of deployment equipment in the Space Shuttle mission in February 1984 provided the first opportunity to test this new retrieval capability. During the launch, the Payload Assist Modules (PAM), which were used to deploy the Westar VI and the Palapa B2 spacecraft, failed after a brief period of ignition, leaving the two spacecraft in an unusable orbit for performing their mission. However, the spacecraft could be maneuvered from the Space Shuttle to a position accessible for retrieval by the Space Shuttle. The success of the Solar Maximum Repair Mission encouraged the idea that these two communications spacecraft could and should be retrieved for future use by interested customers. Subsequently, plans were made; and on the November Space Shuttle mission, the Westar VI and the Palapa B2 satellites were retrieved.

The failures of the Payload Assist Modules prompted an exhaustive examination of production practices by the NASA/industry team; and new test criteria for

Photo taken from aboard the Shuttle Challenger shows Astronaut David C. Leestma (left) and Astronaut Kathryn D. Sullivan (right) at the orbital refueling system in the aft cargo bay. Dr. Sullivan's participation in the extravehicular activity (EVA) shown in this photo is the first such activity for an American women astronaut.

qualifying the rocket motors were established. In October, the new testing procedures proved satisfactory when the Space Shuttle successfully deployed two communications spacecraft and the PAM's placed them on precise geosynchronous transfer orbits. That same Shuttle mission also demonstrated the first use of a "frizbee" technique to deploy a new family of Shuttle optimized communicaitons satellites called Leasat. This deployment and subsequent placement in geosynchronous orbit was hightly successful.

In addition to these firsts, others of significance in 1984 are the first flight of the Orbiter Discovery, the first flight of a Manned Maneuvering Unit; the first landing at KSC; the first flight of a commercial Payload Specialist; the first flight with a 7-person crew; the first mission in space by two female U.S. astronauts and the first female U.S. astronaut to walk in space.

Flight Operations

Flight Operations supports the Space Transportation System (STS) in mission planning, crew training, mission control, and the production of flight software. During 1984, five STS missions were supported, as were preparations for a number of future missions. There were a number of noteworthy accomplishments in Flight Operations during 1984. The Shuttle Mission Simulators now can accommodate crew training requirements for the equivalent of twelve flights per year. In the Mission Control Center (MCC) at the Johnson Space Center, a second Flight Control Room, along with augmented supporting systems, was completed which will enable this facility to support sixteen flights per year. The MCC also now has dual flight function capability so that it can participate simultaneously in two of the following classes of activities: real time mission control and launch pad test or mission simulation. In addition, security provisions were completed for support of DOD classified operations. At Vandenberg Air Force Base, launch capabilities preparations continue on schedule, with the first launch planned for October 1985.

Also during 1984, NASA selected seventeen astronaut candidates who will undergo a year of probationary training prior to final appointment. Seven pilots and ten mission specialists are in this group. This was the tenth group to be selected since the original seven Mercury astronauts were chosen in 1959.

Launch and Landing Operations

Five STS missions were flowin in 1984. Two were on Discovery, the third member of our fleet of Orbiters. In 1984, 14 major payloads were processed for flight and subsequently launched. This is the highest number in a year to-date. The completion of the KSC's Shuttle Processing Contractor (SPC) transition also was accomplished during the year. Additional operational experience gathered in 1984 has reduced hardware turnaround time to 52 working days. A significant contribution to this improvement has been the reduction in Shuttle testing requirements. The near term goal, to be realized in 1985, is 35 days. An indication of this trend can be seen by noting that STS-2 had 11,369 checkout problem reports as compared to 1,043 for STS 41-C.

Orbiter

The Space Transportation System continued to make progress in 1984 toward certification of a four Orbiter vehicle fleet. Challenger flew three missions successfully; and two of these flights (41-B and 41-G) landed at the Kennedy Space Center in Florida, demonstrating the feasibility of the goal of an operational fleet launching and landing at KSC routinely. The initial flight of Discovery was carried out in August, and its second flight occurred in November. Columbia was returned to Palmdale, California, for the modifications required to bring it into an operational configuration after its success as a flight developmental vehicle. These modifications are scheduled for completion in early 1985. The delivery schedule of the fourth flight vehicle, Atlantis, was delayed four months to April 1985 to allow for modifications necessary for the Centaur missions. Upon its delivery, all four Orbiters will be operational.

Space Shuttle Main Engine (SSME)

The main engines performed excellently and reliably on all flights in 1984. The Discovery and Challenger flights, combined with the previous Columbia flights, validated the SSME design; verified the engine certification program; and demonstrated the validity of the engine inspections/maintenance plan and the concept of the SSME Line Replaceable Unit. Engines and/or major subsystems have been replaced on the Orbiter without having to re-hot fire the Orbiter prior to launch. In 1984, Flight Certification Extension testing continued. To date, two test cycles have been completed on one engine, qualifying the SSME for 20 flights. The objective of the test series is to expose the engine to 20 additional starts and accumulate 20,000 seconds on each of two engines.

Plans were initiated in 1984 for improvement in manufacturing to increase the production of flight hardware. The plant modernization projects include a new turbopump fabrication center, an engine overhaul center, plant rearrangement, machine tool modernization, automatic welding and robotic welding. In 1984, a program was begun to increase the life of the high pressure pumps at SSME full power level. Pump life improvement also will result at the lower power levels at which the majority of missions are flown. Larger life pumps will be very beneficial in lowering operations costs. The certification program for the improved pumps will start in 1985.

External Tank (ET)

All Space Shuttle external tanks flown in 1984 performed as expected. Nine tanks manufactured during 1984 were delivered on or ahead of schedule. Cost savings improvements in production continued to be implemented. The first tank for a Vandenberg launch was delivered to the west coast site and is being utilized initially as a checkout vehicle to verify the new launch preparation facilities. At the end of 1984, 15 tanks were in various stages of manufacture at the New Orleans, Louisiana, Michoud Assembly Facility.

Solid Rocket Booster (SRB)

The Shuttle's solid rocket boosters continued to perform as predicted during ascent. Recovery of all boosters was successful; and they are being refurbished for reuse. Twenty boosters, or ten flight sets, were delivered in 1984. The design phase of the filament wound case, which will provide additional payload capability, has been essentially completed. The first of three static test firings was successful, and the composite cases have been wound for the first flight from Vandenberg Air Force Base, scheduled for October 1985. As a result of competitive procurement for the booster assembly contract exclusive of the solid propellant rocket motor, United States Boosters, Inc. (USBI), the current contractor, was selected. As part of this contract, USBI will design and construct an integrated refurbishment and assembly facility at KSC to support the required deliveries to KSC and VAFB for up to 24 launches per year.

Spacelab

The year of 1984 was one of transition for the Spacelab program. The successful Spacelab 1 development mission of 1983 was followed by preparations for the first operational module mission scheduled for early 1985, by deliveries of the second set of Spacelab flight hardware developed by the European Space Agency, and by the flight of various Spacelab hardware configurations. In addition to those mission preparations and hardware deliveries, new developments were initiated in 1984 to better serve the needs of Spacelab customers.

NASA approved and initiated development of a Shuttle Payload of Opportunity carrier known as "Hitchhiker" that will provide to the experimenter with a capability greater than the Get Away Special (GAS), but less than that of the existing Spacelab carriers. The Hitchhiker-G (a Goddard Space Flight Center version) and Hitchhiker-M (a Marshall Space Flight Center version) will provide a space platform in the Shuttle cargo bay for a range of exploratory science and experiments that can be accommodated on short notice and at lower cost. Expectations are that the Hitchhikers will encourage greater use of space and attract new customers for the Spacelab and the Shuttle. Another development in 1984 was the Marshall Space Flight Center Payload Operations Control Center (POCC). The new POCC augments the Spacelab POCC at the Johnson Space Center and is designed to meet future traffic rates and to enhance service to the customer. It is the forerunner of remotely located POCC's (i.e., not colocated with the Shuttle flight control facility) and will increase efficiency of information dissemination to the ultimate user.

Spacelab flight hardware delivered from Europe in 1984 included the Igloo Pallet, Long Module segments, and the first of two Instrument Pointing Systems (IPS). The IPS, a highly sophisticated piece of space hardware, interacts with the Shuttle to provide a directionally stable base for delicate scientific instruments. It will fly for the first time in 1985 on the second Spacelab development test flight.

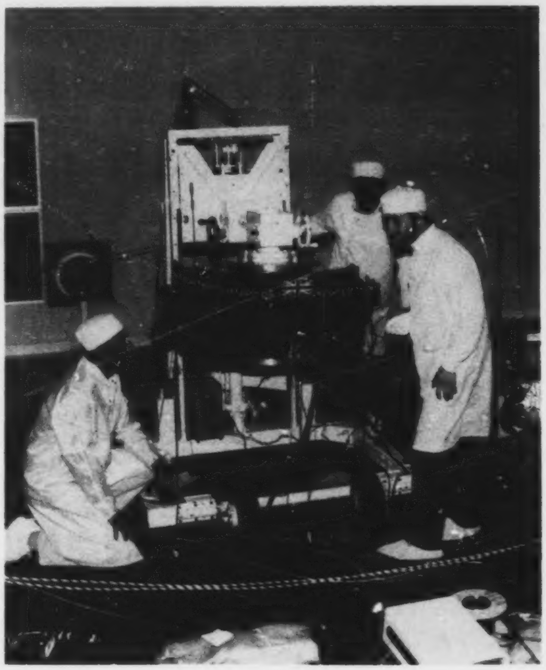
Preparations for that development test flight, for the first operational Spacelab, for mixed cargo missions, and for a special spacecraft retrieval mission all were carried out in 1984. One of the mixed cargo missions was STS 41-D, which included the first operational flight of the Multiplexer Demultiplexer (MDM) pallet configuration of the Spacelab Pallet System (SPS). The Igloo pallet configuration of the SPS will fly in a mixed cargo mode for the first time in 1986. The spacecraft retrieval mission was flown with two Spacelab pallets acting as the Shuttle-to-spacecraft interface to berth two stranded communications satellites (Palapa and Westar) for their return to Earth. The multitude of activities associated with processing these widely different missions has advanced the maturity of Spacelab's operational resources and procedures.

The success of the international, cooperative Spacelab effort was demonstrated further in 1984 by the decision of the Japanese Government to purchase space on a Spacelab module mission in 1988. The Japanese decision follows that of Germany to fly a series of dedicated Spacelab missions beginning in 1985.

Expendable Launch Vehicles (ELVs)

NASA's Expendable Launch Vehicles provided launch support to seven satellite missions during 1984 using four Deltas, one Scout, one Atlas Centaur, and one Atlas-E/F. During this period the Delta vehicle completed its 43rd consecutive successful launch with the launching of the NATO-IIID satellite in November 1984. Delta was used successfully to launch Landsat-D1 in March, AMPTE in August, and Galaxy-C in September. Other payloads launched during 1984 by NASA ELVs included a Navy navigation satellite by Scout, an Intelsat V-A communications satellite by Atlas Centaur, and a NOAA weather satellite by an Atlas-E/F vehicle. The launch of the Intelsat V-A satellite experienced an anomaly in the launch vehicle which resulted in failure to orbit the satellite properly. A review and testing of corrective measures are underway with a plan to resume launching in early 1985. All missions, except the NASA scientific satellite AMPTE, were paid for by Government and non-US Government customers.

Delta, Atlas Centaur, and Scout ELVs are under active consideration by commercial operators for use by private industry. The commercial use of these vehicle systems is in accordance with the President's policy directive of May 1983. An interim agreement has been signed between NASA and Transpace Carriers, Inc. (TCI), for exclusive rights to market the Delta Vehicle; and negotiations are underway with General Dynamics on the Atlas Centaur. Interest for the private use of the Scout Launch Vehicle has been solicited through a Commerce Business Daily (CBD) announcement, published August 8, 1984. Ten companies have expressed interest in assuming a total or partial takeover of this vehicle system. A request for proposal (RFP) is in preparation for release to all interested companies. Production for these vehicle systems is virtually completed; however, NASA will continue to fulfill launch commitments through 1987 for these vehicle systems.



British engineers shown at the Kennedy Space Center in Florida, conducting tests on the United Kingdom Subsatellite part of the three-spacecraft international Active Magnetospheric Particle Tracer Explorer (AMPTE) mission from which scientists expect to acquire valuable new data on how the solar wind interacts with Earth's magnetic fields.

Upper Stages

NASA continues design, development, and procurement of the STS/Centaur upper stage for the Galileo and the Ulysses missions scheduled for flight in 1986. Although under a tight schedule, efforts are progressing satisfactorily. The Air Force is sharing in the design and development costs of this stage to fulfill certain mission requirements. Qualification testing of the Centaur G prime test vehicle was begun in 1984 with completion expected in the first half of 1985. In addition, a preliminary design review for the Centaur-G flight vehicle was completed; and a critical design review was initiated in October. Efforts to resume use of the Air Force-developed Inertial Upper Stage for launching NASA's Tracking and Data Relay Satellite System (TDRSS) are progressing satisfactorily. Launch of TDRSS-B is scheduled for early 1985.

Commercially developed upper stages have played a significant role in space especially McDonnell Douglas Corporation's Payload Assist Module (PAM-D). Except for two failures of the PAMs to place the Westar VI and the Palapa B2 payloads in proper orbits in February 1984, this upper stage has performed successfully for 25 missions on expendable and Shuttle launches since 1980, five of which occurred after the February 1984 failures. NASA continued to work with other upper stage commercial developers such as the Orbital Sciences Corporation (OSC), currently developing the Transfer Orbit State (TOS), a new upper stage which has more capability than the PAM. The TOS will compete with other upper stages for selected missions. At this time, no firm mission users have been identified for the TOS.

Tethered Satellite System (TSS)

Hardware development began in early 1984 for the deployer part of the Tethered Satellite System (TSS). The U.S. and Italy are cooperating on the TSS which will provide the capability to conduct experiments in the upper atmosphere and ionosphere using the Space Shuttle as an orbiting base and up to 100km away. Its first use is planned for late 1987 or early 1988.

Advanced Planning

In 1984, development planning for an Orbital Maneuvering Vehicle (OMV) continued with the selection of three Phase B contractors: TRW, LTV, and Martin Marietta. The program objective is to extend the "reach" of the Shuttle up to 1000 nautical miles for deploying and retrieving spacecraft. It also would support the Space Station.

The in-flight demonstration of hydrazine fuel transfer was completed successfully on Mission 41-G, and marks an important step for satellite refueling. Additionally, other flight experiments have been undertaken, including an experiment to demonstrate astronaut capability and learning required for EVA tasks involving construction and assembly of large structures in space.

A study and laboratory program to define and evaluate several applications of tethers in space began in 1984, and a Letter of Agreement was completed with Italy for continued cooperation in this area. Applications of tethers include: power generation, orbit raising without propellants, artificial gravity, constellations, and others.

Based on Shuttle technology, definition of unmanned cargo vehicles to complement the Space Transportation System continued. Unmanned cargo vehicles will provide increased performance for potential post-1995 missions and will be applicable to potential missions for both DoD and NASA. Studies also were initiated on a reusable Orbit Transfer Vehicle to lower the cost of transportation to geostationary orbit and, eventually, to form the basis of manned orbital transport.

Commercial Use of Space

In 1984, this Administration announced a National Commercial Space Policy to encourage private enterprise in space; and the U. S. Congress endorsed this policy by amending the NASA Space Act of 1958 to include the following provision:

> ". . . the general welfare of the United States of America requires that the National Aeronautics and Space Administration seek and encourage, to the maximum extent possible, the fullest commercial use of space."

The National Policy on the Commercial Use of Space consists of initiatives in four major categories: policy, economic, legal and regulatory, and research and development.

To implement policy, a Cabinet Council for Commerce and Trade Commercial Space Working Group has been established. It will be chaired by a representative from the Department of Commerce with a representative from NASA as Vice-Chairman.

Economic initiatives to encourage the commercial use of space will include efforts to modify tax structure and regulations to provide equitable benefits to space ventures and facilitate government use of commercial space products and services. Legislation was passed in 1984 by the Congress to implement a portion of these goals.

Legal and regulatory initiatives include reexamining regulatory policies governing commercial activities in space in order to provide additional protection with respect to proprietary information, and assure fair international competition.

Initiatives in research and development are to encourage greater participation in space research and development within the private sector and broaden awareness of commercial space opportunities among non-aerospace industries.

In 1984, the NASA Space Commercialization Task Force completed its efforts to develop an agency-wide policy and plan to enhance the agency's ability to encourage and stimulate free enterprise in space.

The Commercialization Task Force reached the following three fundamental conclusions:

(1) Commercial activities in space by private enterprise should begin now to help the nation retain its leadership in science and technology, and its advantages in international trade.

(2) Natural and bureaucratic barriers inhibiting the commercial use of space should be modified or eliminated.

(3) Finally, the Task Force concluded that with determined effort and the commitment of reasonable resources over a number of years, a partnership between government, industry, and academia can turn space into a source of immense benefit for the nation.

To support the National Commercial Space Policy and agency-wide commercial use of space initiatives, NASA established an Office of Commercial Programs to serve as an agency focal point for commercial space endeavors.

The office will work to translate the national initiatives and the results of the NASA Task Force into working policies and programs. It will provide the direction for initiatives from the private sector, particularly new commercial high-technololgy space ventures and new commercial applications of existing space technologies. It will support unsubsidized initiatives aimed at transferring existing programs to the private sector.

The Office of Commercial Programs will work to reduce the financial, institutional, and technical risks of doing business in space.

Significant accomplishments in 1984 by the Office of Commercial Programs included the signing of a Joint Endeavor Agreement between NASA and the 3M Company for long-term research in the organic and polymer chemistry areas. In addition, the McDonnell Douglas Astronautics Company completed its fourth successful flight of the Continuous Flow Electrophoresis System, with the first non-astronaut payload specialist, Charles Walker.

Space Station

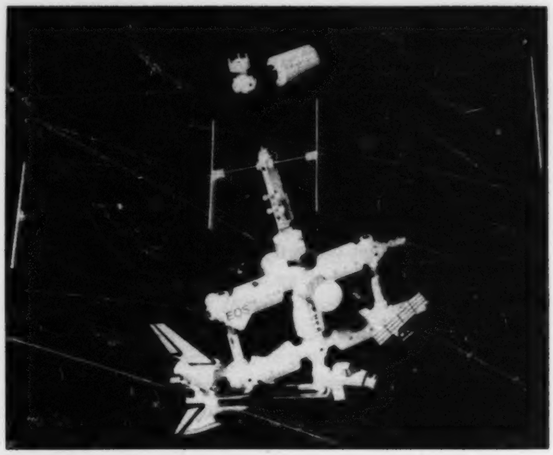
In January of 1984, the President directed NASA to develop a permanently manned space station within a decade, and invited the participation of other nations.

Pursuant to the President's directive, the objectives of NASA's Space Station program are to assure U.S. leadership in space in the 1990's and beyond, promote international cooperation, stimulate the development of advanced technologies, enhance capabilities for space science and applications, develop and encourage private investment in the commercial use of space, and stimulate interest in scientific and engineering education.

The Space Station is to be a multi-purpose "customer friendly" facility serving the interests and requirements of users in the field of science, commerce, and technology. It will be designed and operated to satisfy multiple customer requirements.

Planning. By the early or mid 1990's, NASA plans to have an operational Space Station able to grow both in size and function and perform effectively for several decades into the 21st century. It will be assembled in orbit, and placed about 300 miles high with an inclination to the equator of 28.5 degrees. It will have a number of pressurized modules and support a crew of six to eight people.

As part of the overall program, two or more unmanned free-flying scientific platforms may be developed for use with the Space Station and may include one in a polar orbit, and another co-orbiting with the Station. A maximum of common subsystems such as power, thermal, docking and data processing will be used on both the Space Station and the platforms. The platform(s) in the 28.5 degree inclination orbit will be tended and serviced by the Space Station. The platform(s) at polar orbit will be launched and serviced by the Space Shuttle.



Model of a space station configuration by McDonnell Douglas Astronautics Company. Huntington Beach, CA.

A key aspect of Space Station planning is that of "evolutionary" growth. As better information is obtained from living and working in space and as new requirements arise, new capabilities could be added to the basic Space Station. The ability to adapt to emerging requirements will enable the Space Station to serve many uses well into the 21st century.

Management and Engineering Guidelines. NASA guidelines for Space Station planning relate both to management and engineering.

Management guidelines include a three year period of detailed definition to minimize cost as well as technical and schedule risks. Throughout the planning process, extensive user involvement is anticipated from the scientific and technological communities and from commercial interests.

Engineering guidelines include planning for growth as well as on-board maintenance and semi-independence from ground control. Station design will include the potential to accommodate increased capabilities by the use of an Orbital Transfer Vehicle. Consideration also will be given to ways to advance automation and robotics and to enhance the human capability to live and work in space.

A Space Station Program Office, established at NASA Headquarters, is responsible for policy and overall program direction. This includes defining requirements, establishing overall schedule and budget guidelines, and handling external programmatic considerations and agreements with other departments and agencies, the Congress, and potential international participants.

The Johnson Space Center has been designated the "Lead Center" for Space Station program management and technical implementation. The Center will be responsible for the management of systems engineering and integration (SE&I), operations, customer integration, and advanced technology development.

Several other NASA Centers have been assigned discrete project mangement responsibilities for different Space Station elements. The Centers manage element SE&I; analyze and incorporate user requirements into elements; define, develop, and integrate system elements; implement advanced development technology projects and prepare project budgets, schedules and other documentation for their portion of the Space Station program.

International Participation. A major objective of the Space Station Program is international participation, with funding to be provided by the participating governments. Foreign participants are to conduct their own definition and preliminary design programs parallel with the NASA activities. Among the sovereign powers interested in the Space Station Program are Canada, Japan and the nations of the European Space Agency.

Three types of possible international participation are envisioned: (i) a "User" who defines missions and utilizes Station capabilities, (ii) a "Builder" who participates in definition and development programs and who contributes to station capabilities, and (iii) an "Operator" who supports the operational phase.

In September of 1984, representatives of the interested countries as well as representatives from U.S. industry began reviewing a NASA Request for Proposal (RFP) for the definition and preliminary design of the Space Station. In addition, a Working Group at NASA Headquarters was established to develop guidelines for international participation. The potential for such participation also was discussed in 1984 at the London Economic Summit where the President explained the U.S. program to the Prime Ministers of the United Kingdom, Italy, Japan and others.

NASA has more than twenty-six years of experience with cooperative international programs, including the work in 1984 with the European Spacelab and the Space Shuttle's Canadian Remote Manipulator System. This cooperation has provided the basis for achieving meaningful international participation in the U.S. Space Station program. At the same time, within these cooperative efforts, preservation of the integrity of U.S. technology has been maintained as well as that of the international partners. The combined expertise and knowledge achieved through international cooperation will expand Space Station capabilities beyond what could be achieved by any nation alone.

Mission Requirements. Mission or payload requirements are the starting points for Space Station design. They define the capabilities that are sought for the Space Station. During 1984, mission requirements were reviewed throughly, a process critical to definition and preliminary design.

Three categories of missions have been established: (i) Science and Applications, including Astrophysics, Earth Science and Applications, Solar System Exploration, Life Sciences, Material Science, and Communications; (ii) Commercial, including Materials Processing in Space, Earth and Oceans Observations, Communications, and Industrial Services; and (iii) Technology Development, which includes Materials and Structures, Energy Conversion, Computer Science and Electronics, Propulsion, Controls and Human Factors, Space Station Systems/Operations, Fluid and Thermal Physics, and Automation and Robotics.

A particularly important activity during 1984 was the establishment of a scientific advisory committee chaired by Dr. Peter Banks of Stanford University. This committee will provide expert advice to NASA on how the Space Station can best serve the various scientific communities.

Program Status. The Space Station RFP included four work packages covering the definition and preliminary design of Space Station elements. NASA contracts to U.S. industry for each of the work packages will be awarded on a competitive basis. The work packages are divided as follows:

(i) Definition and preliminary design of pressurized "common" modules with appropriate systems for use as laboratories, living areas and logistics transport; environmental control and propulsive systems; plans for equipping one module as a laboratory and others as logistics modules; and plans for accommodations for orbital maneuvering and orbital transfer systems.

(ii) Definition and preliminary design of the structural framework to which the various elements of the Space Station will be attached; interface between the Space Station and Space Shuttle; mechanisms such as the Remote Manipulator System; attitude control, thermal control, communications and data management systems; plans for equipping a module with sleeping quarters, wardroom and galley; and plans for extravehicular activity (EVA).

(iii) Definition and preliminary design of the automated free-flying platforms and of provisions to service and repair the platforms and other free-flying spacecraft; provisions for instruments and payloads to be attached externally to the Space Station; and plans for equipping a module for a laboratory.

(iv) Definition and preliminary design for electrical power generation, conducting and storage systems.

The RFP requires contractors to study changes to the Space Station elements, if the Station is to be tended initially by personnel for varying periods rather than permanently manned.

Proposals for the Program Definition and Preliminary Design were received in November 1984 from U.S. industry and are under review by NASA. Contract awards for the four work packages are expected to be of 21 months duration and to be made in the spring of 1985.

Advanced Development Technology Test Beds. Advanced Development Technology test beds were initiated in 1984. The purposes of the test beds are several. They will help identify emerging technologies for advanced development necessary to enhance Space Station design; and they will provide technology options for the initial station capability. Further, inter-center teams will carry out technology development activities and facilitate the incorporation of advanced technology into the Design, Development, Test and Engineering (DDT&E) phase of the Space Station program.

The test beds, to be located at various NASA Centers, will be in the fields of Data Management Systems, Environmental Control/Regenerative Life Support Systems, Electrical Power Systems, Attitude Control, Auxiliary Propulsion, Thermal Management System, and Space Operations Mechanisms.

Many significant activities were accomplished in 1984 in response to the President's directive for the Space Station Program. These emphasized management planning, technology development and preliminary engineering as well as the pursuit of international cooperation and increased involvement by U.S. industry. As NASA moves forward with the Space Station Program, industrial and international participation can be expected to grow.

Space Tracking and Data Systems

The Space Tracking and Data Systems Program in 1984 continued to provide support for tracking, command, telemetry, and data acquisition for all NASA programs by means of the Space Network, the Deep Space Network (DSN), the Spaceflight Tracking and Data Network (STDN), and various other facilities. A global communications system links tracking sites, control centers, and data processing facilities which provide real-time data processing for mission control, orbit and attitude determination, and routine processing of telemetry for space missions.

The transition from the traditional mode of ground network support of low Earth orbiting spacecraft Space Network, which began in 1983 with the first Tracking and Data Relay Satellite (TDRS), continues toward its ultimate objective: an operational Tracking and Data Relay Satellite System (TDRSS), presently projected for 1986, when many of the existing ground stations no longer will be required and will be closed or transferred to other agencies. The stations remaining in California, Australia, and Spain will be consolidated with the Deep Space network under the operation and management of the Jet Propulsion Laboratory (JPL); and two will be dedicated to launch and landing support. This consolidation will provide a single ground network for all deep space probes and planetary missions, spacecraft in geosynchronous and highly elliptical orbits, as well as the few older spacecraft which are not compatible with the TDRSS.

Space Network. The Space Network consists of the Tracking and Data Relay Satellites and the White Sands Ground Terminal, the NASA Ground Terminal co-located with the White Sands Ground Terminal in New Mexico, the Network Control Center, the Operations Support Computing Facility, the Simulations Operations Center, the Compatibility Test Vans, and the Bilateration Ranging Transponder System.

The launch of the first Tracking and Data Relay Satellite (TDRS) in 1983 was a significant step toward an operational Space Network. Exceptional support was provided to a variety of Space Shuttle missions and numerous Landsat events in 1984 by the first TDRS.

The launching, projected for 1986, of two additional TDRS and, ultimately, the completion of required testing, will advance the TDRSS to full operational capability. This will complete the transition to the new era of operational support of low Earth orbital missions.

Ground Networks. The Ground networks consist of the Spaceflight Tracking and Data Network (STDN), the Deep Space Network (DSN), and ground tracking and data acquisition support for the Aeronautics, Balloons, and Sounding Rocket Programs. Support provided by the ground network was for both NASA's near-Earth orbiting satellites, including the Space Shuttle operational flights, and for deep space probes. Numerous applications and scientific Earth orbiting missions also were supported in 1984, and included the Active Magnetospheric Particle Tracer Explorer, Nimbus-7, NOAA Landsat, International Ultraviolet Explorer, International Sun Earth Explorers, Solar Maximum Mission, and the Solar Mesospheric Explorer. Planetary mission support continued for Pioneers 10 and 11, Pioneer Venus, and Voyagers 1 and 2, as well as limited support for Helios and earlier Pioneer missions. In addition, the DSN assumed responsibility for tracking and data support for the International Cometary Explorer (ICE) in 1984.

Major upgrading is underway to increase the support capability of the DSN for spacecraft bound for distant planets. The upgrading in 1984 was designed to enhance the ability of the DSN to receive weaker signals, provide support to an increasing variety of spacecraft, and provide more precise navigation. A critical milestone for this activity is to increase the capability of the DSN to support Voyager 2's encounter with Uranus in early 1986.

Control Centers, Communications, and Data Systems. The basic elements of this program form the vital link between the data acquisition stations and the users, and include communications, mission control, and data processing. Emphasis continued in 1984 on the development of a control center for dedicated support to the Space Telescope. Major software developments underway for several years are nearing completion. This software consists of some one million lines of code and manages the major operational activities of the mission. Modifications are underway to the existing multisatellite operations control center for control of the upcoming Gamma Ray Observatory (GRO) and the Cosmic Background Explorer (COBE).

Telemetry data processing for ongoing missions continued in 1984. Planning, systems implementation, and testing continued for support of upcoming new missions such as the Space Telescope and future Spacelabs.

The Communications Program for the Office of Space Tracking and Data System (OSTDS) is comprised principally of two major components: NASA Communications (NASCOM) and Program Support Communications (PSC) which consist collectively of almost 3 million miles of circuits with associated switching and terminal facilities. Operational communications support for all flight projects is provided by NASCOM. This global network connects NASA's remote tracking sites with the agency's field centers; it will be reduced in size in concert with the closing of ground network stations. A Time Division Multiple Access (TDMA) system will serve the remaining stations using advanced digital techniques which allow transmit/receiving connections to be adjusted to meet the communications requirements.

Programmatic and administrative operations at all NASA centers and Headquarters are provided by the Program Support Communications Network (PSCN).

Space Research and Technology

The NASA space research and technology program provides the scientific and technological advancements that enable the United States to lead in the exploration of the solar system, in communications, and in earth observations from space. The major disciplines include propulsion, space energy conversion, controls and human factors, space data and communications, computer science and electronics, materials and structures, and aerothermodynamics. In addition to these disciplines, the program supports R&T Space Flight Experiments. The NASA space research and technology program is conducted by NASA Centers, private industry and the university community.

Disciplinary R&T.

The technology base for the research and technology program spans several disciplines.

Propulsion. The technology for advanced reusable Earth-to-orbit propulsion systems continued to make advances in 1984 toward developing longer life components. Analytical modeling and experiments improved understanding of the interaction between fluids and rotating mechanical parts. This resulted in the development of damping seals for high-speed turbopumps that will greatly reduce shaft dynamics and associated high bearing loads. In the bearing research program, itital thermal modeling of rolling element bearings operating in a cryogenic environment was completed. Testing of bearings began to validate and upgrade the new model as necessary. For propulsion of orbital-transfer vehicles, the program focused on critical subcomponents. For example, testing to evaluate combustor walls designed for enhanced heat transfer to increase turbine drive gas temperatures was initiated in 1984. Hot air was used to simulate combustion gases. Tests looked for materials that could be used for turbine blades operating with oxygen as the turbine working fluid. Research efforts also sought material candidates and fabrication techniques for high-expansion-ratio, aerodynamically efficient exhaust nozzles.

Space Energy Conversion. The joint DOE/DOD/NASA nuclear reactor space power program continued to evaluate various energy conversion system options, now reduced to three: thermoelectric, thermionic, and Stirling cycle conversion systems. System contractors selected for each of the concepts made significant progress in resolving technical issues of efficiency, stability of high-temperature materials, and system life.

Research on photovoltaics energy systems progressed substantially during 1984 in the technologies of high performance solar cells and large arrays. For silicon solar cells, increases in efficiency were achieved through surface passivation and provision for cell transparency to the infrared portion of the solar spectrum. Decreased weight occurred through reductions in cell thickness, the use of gridded back contacts, and increased efficiency. Significant technological progress occurred in 1984 on multiple bandgap cells, such as gallium-indium-arsenide and gallium-arsenide-phosphide, potentially capable of achieving 30-percent efficiency. Advanced designs that result in reduced blockage of incident sunlight and in improved pointing control also have been made in gallium arsenide concentrator arrays. These arrays offer potential for significant reductions in size and cost compared to planar configurations.

Future space systems, which may consume several hundred kilowatts of power, must deal with large electrical currents and heat flows. To address these needs, a new research program investigates high strength, lightweight electrical and thermal conductors made of intercalated graphite. Graphite fibers intercalated with bromine showed a factor of 5 increase in electrical conductivity and demonstrated very high current-carrying capability without degradation.

Nearly all of the power generated aboard a space station must be radiated to space as waste heat. Conventional flat-plate or tube-and-fin radiators, plus their meteoroid armoring, would be so heavy as to dominate systems design tradeoffs. One promising new idea, the liquid drop radiator, radiates waste heat from a recirculating free stream of liquid droplets in place of a solid surface. In concept, the liquid absorbs space station heat; then it is sprayed in a tightly controlled stream to a distant receiver, radiating heat on the way. The liquid system would be lighter, less susceptible to damage by meteoroids and easier to transport to space than conventional systems. Laboratory spray and heat transfer tests in 1984 encourage continued research.

In 1984, integrated breadboard tests of two types of the fuel-cell and water-electrolyzer systems were initiated to verify the concept of regenerative fuel cells technology for power generation and energy storage. Testing of a breadboard system, which uses an acidic solid-polymer electrolyte, successfully achieved experimental goals with 3000 hours of operation, obtained using duty cycles representative of low-earth-orbit conditions. Design, fabrication, and final assembly of the alternative alkaline breadboard system were completed; and testing began at the end of 1984. In the technology for higher-capacity, long-life, high-energy-density batteries, experimental advanced concept primary lithium cells were produced successfully in the dry room facility established in 1984.

Controls and Human Factors. Research focused on controlling such large flexible space systems as may be developed in the future, e.g., a space station larger and more complex than the initial version, large antennae, and large astrophysics telescopes. During 1984, the technology for a precision shape sensor, capable of simultaneoulsy measuring the motion of as many as 50 positions on a space structure, was tested in the laboratory. The test demonstrated a position accuracy measurement of less than 2mm from a ranging distance of 10 meters. In teleoperation, the largest piece of the human factors program, the activity goes beyond the Remote Manipulator System (RMS) currently used on Shuttle orbiters to the development of free-flying, two-armed, remote manipulators which can be used to service satellites, the Shuttle, and Space Station and to assemble structures. Major accomplishments of 1984 are in the area of intelligent displays and augmented controls for use by an operator.

Space Data and Communications. A Charge Coupled Device (CCD) for imaging of astronomical objects was demonstrated in 1984 by successfully imaging the radiation emanating from a laser-generated plasma at the University of California. It has X-ray sensitivity to energies as low as 277 eV with spectral resolution as good as 215 eV. This device can image objects in the wave-length region from UV to 584 angstroms. Further development may lead to a low-cost 1024 by 1024 pixel CCD for use in solar and planetary applications as well as provide enhanced astrophysical performance such as enhanced UV and x-ray sensitivity, good spectral resolution and improved charge collection for spatial imaging.

Technology for a 55-meter diameter, offset wrap-rib antenna that would support a nationwide mobile communications system was demonstrated for the first time during 1984. An antenna segment, consisting of 4 ribs and three gores, was fabricated and successfully ground tested in deployment and retraction tests.

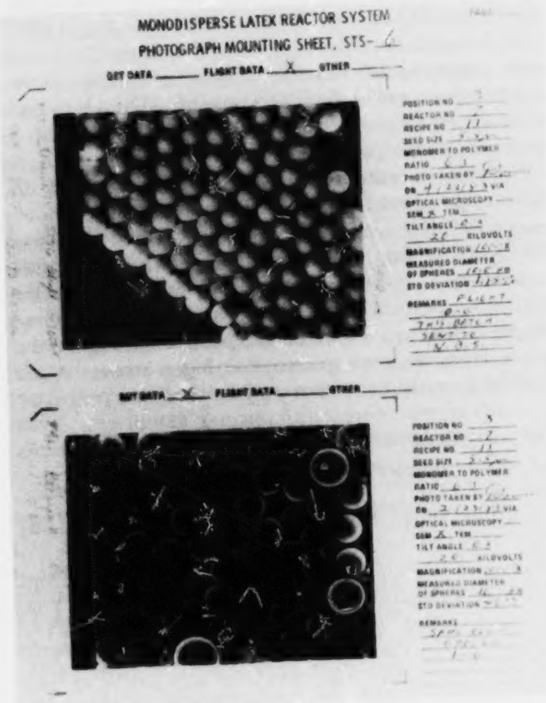
Computer Science and Electronics. An Optical Disk Buffer (ODB) is under development through an interagency R&D program involving NASA, the Department of Energy, the U.S. Air Force, the Central Intelligence Agency, and the Defense Mapping Agency. The objective is to provide both the Space Station and government supercomputer facilities with an ultra-high performance data storage unit. The ODB will store one trillion bits of information with a data transfer rate in excess of one billion bits per second. The optical disk unit delivered to Marshall Space Flight Center in 1984 provided critical technology which has been combined with advances in erasable media and laser diode technology to make the ODB possible. The ODB will be designed for both space and ground usage, with a total volume of less than one cubic meter.

NASA's coordination with the Department of Defense program in Very High Speed Integrated Circuits (VHSIC) has resulted in identification, during 1984, of the first potential civil applications of this technology. Candidates include a custom processor for synthetic aperture radar data for use in the Venus Mapper Mission, a general purpose processor for the Space Station, a programmable logic array for the Shuttle propulsion system and a baseband processor for advanced communictaions satellites. This technology promises to meet the five million operations per second required for the Space Station general purpose processor.

During 1984, major performance improvements were realized in an automated planning program which uses artificial intelligence techniques to plan and schedule spacecraft operations automatically. This planning system, which has been tailored for use by the Voyager Project during the encounter of Uranus, now exhibits sufficiently high levels of sophistication and capability for realistic planning of major mission sequences involving as many as a hundred distinct tasks. This computer program, known as DEVISER, is being coupled with programs for execution of monitoring and fault diagnosis to yield a laboratory demonstration of a rudimentary system for autonomy, a key capability for future space missions.

Materials and Structures. During 1984, materials research and technology significantly contributed to the national space effort. Over an area of 4000 sq. ft. on Shuttle Orbiter Discovery 1, 2300 flexible woven ceramic blankets replaced 8000 ceramic tiles. This new thermal protection system (TPS) is much more durable than the original TPS, without loss of performance or additional weight penalty. While research in advanced TPS will continue, the flexible blankets represent a major improvement.

During 1984, studies conducted under space environmental effects research showed the amount of man-made debris in stable orbits to be much greater than was thought a few years ago. While the absolute risk of impact is small, the potential danger to both low-orbit and geosynchronous satellites cannot be ignored; and the effects of hypervelocity impact by debris and meteoroids must be considered in planning extended space operations. In another environmental effects research effort, accelerated test techniques have been developed and evaluated corresponding to a 30-year exposure of polymeric materials to the conditions found in a low earth orbit. The research is being supported by the unique ground-based Space Environmental Effects Facility at the Langley Research Center.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REMARKS

The advantages of space processing, the higher degree of refinement from materials produced in space, are evident in this comparison of electron microscope views of monodisperse latex particles made on Shuttle flight STS-6 (top photo) with those made on Earth (bottom photo) using the same chemical recipe and identical hardware. Those made on Earth, under the pull of gravity, are deformed, off-sized and show other imperfections.

Microgravity Science and Applications. On July 17, 1984, NASA officially transferred to the National Bureau of Standards (NBS) 10 micron diameter monodisperse latex beads which had been processed on board the Space Shuttle. NBS currently is characterizing the spheres; and plans are to release them for sale in 1985 as primary standards. This is part of their Standard Reference Material (SRM) program which is administered in conjunction with the American Society for Testing Materials. The latex beads are the result of a NASA-sponsored program which is investigating the processing of monodisperse beads in low gravity for sizes up to 100 microns diameter. NBS would like samples of the larger sizes when they become available for possible use in the SRM program; currently NBS is evaluating the quality of 30 microgram diameter beads which were produced in limited quantities on a recent Shuttle flight.

In 1984, some preliminary results were obtained for a Germanium Selenide (GeSe) vapor crystal growth experiment performed on the OSTA-2 mission. Typical of space processed crystals, the GeSe crystals are larger, more regular, with a low defect density. In addition, the crystals appeared to be formed in the center of ampoule, (away from contact with the walls), indicating a pattern of homogenous nucleation. In general, crystals formed by homogenous nucleation will have a lower defect density. The result should be high quality crystals being produced in subsequent space experiments which will study vapor growth of other materials such as the technologically interesting mercury cadmium telluride.

In 1984, the McDonnell Douglas Aerospace Corporation (MDAC) continued efforts to commercialize the processing of biomaterials in space using a Continuous Flow Electrophoretic System (CFES). On a recent Shuttle flight, a "preproduction" run of proprietary materials using CFES was conducted.

Aerothermodynamics. Rapid progress has been made in defining the aerodynamic heating to be encountered by orbital transfer vehicles, transatmospheric vehicles, and planetary return vehicles, which may use aerobraking and aerocapture for maneuvering or for braking upon return to Earth. Recent studies have shown that the use of the Earth's upper atmosphere for retro-braking and plane change maneuvers at orbital and higher speeds involves considerable nonequilibrium chemistry effects on the heat transfer to the spacecraft. The complex chemical reactions important in heating are difficult to verify experimentally and hence mathematical modeling of finite-rate chemistry must be carried out for the flow fields about the spacecraft. This requires computationally intensive modeling; however, a recent breakthrough in aerothermodynamics algorithms for modeling complex flows

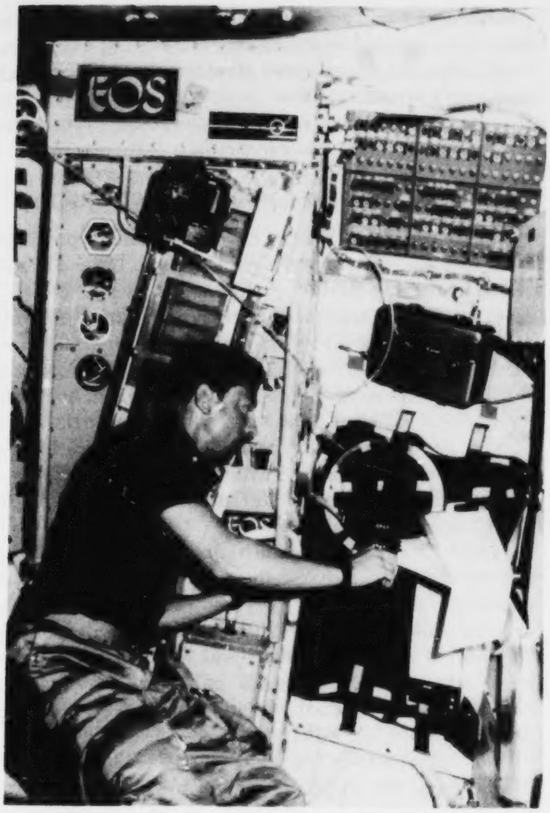
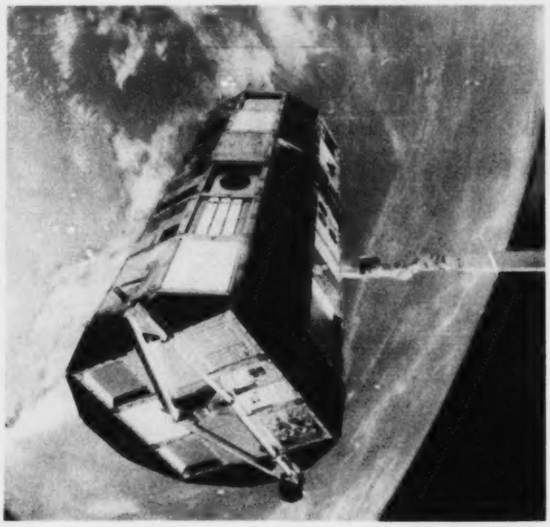


Photo taken onboard Shuttle Discovery in earth-orbit shows the first non-astronaut payload specialist Charles D. Walker closing a storge area for biological samples for the McDonnell Douglas Aerospace Corporation continuous flow electrophoresis experiment in the mid-deck of the Shuttle. Just beyond Walker's shoulder is the see-through upward flowing processing canal for the biological sample. A fixed 35mm camera records the flow during which a separation and purification process takes place.

allows rapid solution to the governing flow equations including the complex chemistry required. This breakthrough will enable rapid, accurate parametric studies to be accomplished with significantly reduced computer resource requirements.

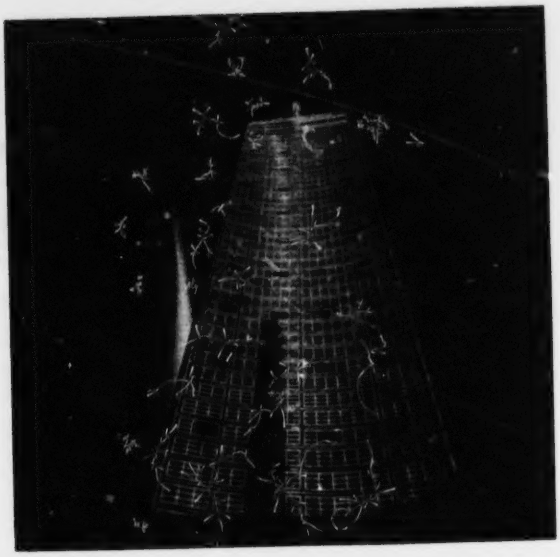
In a companion effort to define the flow fields and aerodynamic heating about advanced space transportation system (shuttle-like vehicles) at high angles of attack (greater than 30°), a flow code has been produced which is capable of accurate flow simulation for the windward side of vehicles. This flow code has been verified by comparison with entry flight data obtained on the Shuttle Orbiter. This validated code will be used to define the aerodynamic loads and surface heating in advanced concepts of space transportation systems.



The Long-Duration Exposure Facility (LDEF) suspended high above the Gulf of Mexico by the remove manipulator system (RMS) prior to releasing it into space. Carried into Earth orbit by the Space Shuttle Challenger, LDEF will be retrieved from space after nine or ten months by a future Shuttle mission.

R&T Space Flight Experiments

In Space Tests and Experiments. Two significant events in the use of the Shuttle to advance space technology occurred in 1984. First, the Shuttle Orbiter Challenger delivered the Long Duration Exposure Facility (LDEF) into orbit in April 1984. LDEF carries a total of 57 technological experiments on materials and components and scientific investigations of the space environment. After one year in space, LDEF returns to Earth via another Shuttle flight for the experiments on the effects of in-depth analysis of long-term exposure in space. The second event of significance happened during August—September, 1984, when the Shuttle Orbiter Discovery, lifted three experiments in one payload devoted to space solar power technology: the Solar Array Experiment, the Dynamic Augmentation Experiment, and Solar Cell Calibration Facility. At the heart of the payload was a large, lightweight, flat, folding solar array consisting of 84 panels. When fully extended, the array rose more than 10 stories above the Shuttle Orbiter cargo bay. Yet, when stored for launch and landing, the array folded into a package only 7 inches thick. The Shuttle crew performed numerous successful deployments and retrievals of the array. During this operation and while the array was extended, the Dynamic Augmentation Experiment observed



The giant solar array experiment panel for the OAST-1 payload of Shuttle Orbiter Discovery, photographed through aft flight deck windows with a 70 mm camera, stands out against the darkness of space. The vertical stabilizer of Discovery is silhouetted against the accordion-like aray.

the solar array using an on-orbit method to determine dynamic characteristics of large highly flexible structures for space systems. The Solar Cell Calibration Facility performed experiments to compare in-space performance of solar cells with similar solar cells tested during high-altitude balloon flights, thus providing a validation of the inexpensive balloon method of obtaining predictions of solar cell characteristics for space missions.

A flight test of the Feature Identification and Location Experiment (FILE) was conducted in October 1984 aboard Shuttle Orbiter Challenger to demonstrate advanced sensor technology for the autonomous classification of Earth's surface features into vegetation, bare earth, water, clouds, snow, and ice. This technology has application for providing pointing information for future earth observation, instrumentation, and navigation systems.

Orbiter Flight Test Experiments. Use of the Shuttle Orbiter as a test bed for the development of technology for advanced transportation systems moved ahead in 1984. Work began on Columbia for installation of Shuttle-related flight-test instruments: an upper atmosphere mass spectrometer, the Shuttle infared leeside temperature sensor, and the Shuttle entry air data system. Data from these instruments will contribute significantly to the aerodynamic and aerothermodynamic data base in the entry flight regime. Shuttle Orbiter Challenger carries a high resolution accelerometer package which supplies data for determining the aerodynamic characteristics in the free molecular and transitional flow regimes. These data also provided information on density waves in the upper atmosphere which must be accounted for in the design of advanced space systems.

Aeronautics Research and Technology

The aeronautical research and technology program at NASA has contributed significantly to United States world leadership in the development of a safe and efficient civil air transportation system and superior military aircraft. To maintain that preeminence, NASA's program is based in the technological disciplines and spans the flight spectrum from hovering to hypersonic flight. Sophisticated wind tunnels, computers, simulators and experimental flight vehicles are examples of the research facilities which NASA uses to meet today's challenges and to provide the tools to design tomorrow's aircraft.

NASA scientists see as a major goal in aeronautics the ability to numerically simulate, rapidly and routinely, the complex three-dimensional flow of air around a flight vehicle. The Numerical Aerodynamic Simulation (NAS) program will develop the world's most advanced aerodynamic computational facility, capable of achieving one billion operations each second and improving the efficiency of the design process.

The interaction of flight crews with vehicle controls, displays and the air traffic environment are important factors in the safety and efficiency of aircraft operations. During 1984, NASA dedicated the Man-Vehicle Simulation Research Facility, equipped with advanced simulators and a computerized air traffic environment, to investigate aircrew limitations and capabilities. Research will be conducted to enhance safety, improve flight deck instrumentation, and solve other human related problems.

Disciplinary R&T

NASA's disciplinary aeronautical research activities provide the long range effort necessary to maintain the preeminence of U.S. civil and military aviation. This research is directed at improving the understanding of basic physical phenomena and developing new concepts in the areas of Fluid and Thermal Physics Materials and Structures, Controls and Guidance Human Factors, and Information Sciences.

Fluid and Thermal Physics. In 1984, a new program focus in computational fluid dynamics was established that will lead to a better understanding and analytical characterization of highly complex internal flows and processes common to gas turbine engines and other aeropropulsion systems.

A series of wind tunnel and full scale flight tests to investigate the effects of natural laminar flow over extensive regions of wings and other aircraft surfaces was completed. Eight different airplanes, representing business and commercial transport aircraft, were used in these flight experiments which clearly demonstrated the ability to achieve and maintain natural laminar flow on modern airplane surfaces.

Laminar Flow Control concepts which create and control a laminar flow of air across difficult surfaces (such as the leading edge of a wing) also are being studied. Flight acceptance tests of two different systems were completed in 1984 on a JETSTAR aircraft as a precursor to extensive research flight evaluations and operational testing of these systems.

Materials and Structures. NASA aeroelastic research has developed a decoupler pylon which suppresses the flutter characteristics of the combined wing/pylon/external ordnance system. Flight testing on an F-16 fighter successfully demonstrated the feasibility of this concept. This technology could increase the amount and type of external ordnance carried on existing fighters and will reduce external systems integration problems on future fighters.

Five shipsets of composite horizontal stabilizers were installed and are now in operational service on the Boeing 737 aircraft. Extensive use of composites in commercial aircraft will reduce gross weight and fuel consumption significantly.

A major activity to develop ceramics for use in the hot section of gas turbine engines continued in 1984. Ceramic components will be able to operate at higher temperatures than metallic components without the aid of cooling air and thus will contribute to more efficient engines than those built today. An optimal structural tailoring procedure was completed which provides the capability of designing stages of engine blades weighing 30% less than those designed by conventional procedures.

Controls and Guidance. A resident back-up software concept was flight tested successfully on the NASA F-8 Digital-fly-by-wire aircraft. This concept provides reliability in case of errors in the primary software, and is an attractive alternative to back-up hardware. Improved aircraft flight modeling techiques were developed which can predict aircraft performance under all flight conditions and reduce expensive flight testing. These techniques are being evaluated in a cooperative program with Boeing Commercial Aircraft Company.

In a joint program with the Army and the Navy, new phosphors were developed which will permit full color, high resolution, thin film electroluminescent flat panel displays for aircraft cockpits.

Human Factors. NASA researchers have completed the first half of a crew fatigue and circadian desynchronosis (jet lag) program by gathering a data base on short-haul commercial airline crews. The long-haul portion of the study has been initiated. This study will assist airline crews in minimizing the effects of fatigue and circadian desynchronosis. In addition, researchers have developed methods for predicting workload and are compiling a handbook on workload measurement.

Information Sciences. The Research Institute for Advanced Computer Science (RIACS) completed its first year of operation. RIACS was formed to advance agency capabilities in aerospace computer science by strengthening ties with the university and industry research communities. The on-going core research program focused on a project which combines concurrent processing and expert systems.

Systems Research

Systems research and technology programs integrate the results of research in the various disciplines to provide an understanding of the interactions among system components. The current programs are focused on those technologies directed at improved propulsion systems, short takeoff/vertical landing (STOVL), advanced turboprops and supersonic cruise.

Advanced fighter concept tested in the NASA Langley 4 × 7 Meter Wind Tunnel using this 30 percent scale model General Dynamic E-7 advanced fighter, one of several powered-lift short takeoff and vertical landing (STOVL) approaches in which NASA is interested.

Powered Lift. An ejector augmentor concept design for a single engine, supersonic, short takeoff/vertical landing (STOVL) fighter successfully completed powered ground effect, and high speed, unpowered tests in two wind tunnel programs. A second concept using plenum chamber burning also was tested in model scale in a high speed wind tunnel.

Two major joint international activities were initiated in 1984. The first was a cooperative program with Canada to test a large scale ejector STOVL model in the 40 + 80 ft. wind tunnel. The second was a planning activity with the United Kingdom to define a cooperative advanced STOVL technology program.

Supersonic Cruise Technology. Dramatic improvements in advanced fighters to allow sustained supersonic cruise, long range, high maneuverability, high acceleration, rapid turn rates and perhaps even STOVL operation can be achieved due to rapidly evolving gas turbine engine technology. A twin-boom supersonic cruise fighter is an initial concept that incorporates curved leading edge supersonic wing, advanced titanium structure, a thrust vectored nozzle and the Turbine Bypass Engine concept. Studies indicate significant potential benefits in every area of performance to include STOVL operations. Recent improvements in computational methods have been applied to analyses of very high supersonic flight, in particular to a Mach 4.5 airplane concept. In addition, the design of a Mach 5.0 dual (over/under) inlet wind tunnel model was completed.

Propulsion Systems R&T Research. Progress continued in advanced instrumentation that allows non-intrusive evaluation of flowfields. A color rainbow schlieren system was developed and used to study the shock waves around a supersonic inlet. Color coding of the disturbance magnitude in the flow provides quantitative information on expansion waves, boundary layers, shock waves and other flow phenomena.

A single cylinder diesel test rig achieved the brake specific fuel consumption goal required for the diesel to be competitive with advanced spark-ignited engines. As a result of these tests, diesel engines, with their ability to use various types of fuel, could be considered for use in general aviation aircraft.

Advanced Turboprop Program. The final design of the large-scale (nine foot diameter) propeller was completed. The high speed, swept propeller was designed with acceptable blade deflections and stresses, no predicted flutter, good performance and acceptable noise. Fabrication of the propeller assembly is underway in preparation for static and wind tunnel tests. Experimental programs were conducted which evaluated propeller configurations (single or counter-rotating), location on an airframe, noise radiation patterns and effects on low speed stability and control characteristics. The results will enable designers to chose an optimum configuration for advanced testing.

Helicopter Technology. NASA began a program with the four major U.S. civil helicopter companies (Bell, Boeing-Vertol, Hughes, and Sikorsky) to identify near-term NASA technology that has a high probability of commercial application to public service uses and Emergency Medical Services (EMS) in particular. The Phase I study will identify EMS and other public service users' helicopter and on-board equipment interface requirements and associated technology needs. Phase II will be directed at the implementation of the technology and technology transfer activity. The effort is being coordinated with the FAA, Coast Guard, Naitonal Highway Traffic Safety Administration, DOD, and appropriate segments of the public service and medical community.

Two successful helicopter icing tests were completed. A pneumatically operated rotor blade deicer boot was flown in artificial and natural icing conditions. In addition, ice shapes on the leading edge of a rotor blade and in flight performance data were obtained to correlate analytic and wind tunnel results of rotor performance degradation due to ice.

Military Support

NASA conducts numerous joint programs with the Department of Defense to insure the continued superiority of U.S. military aviation. These programs include both rotorcraft and high performance aircraft.

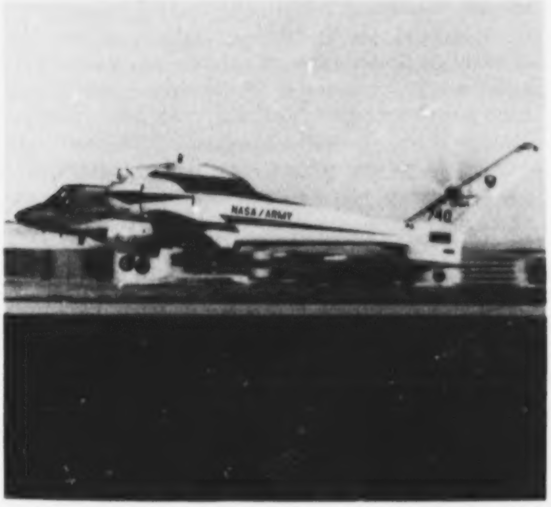
Advanced Fighter Technology Intergration (AFTI). The joint Air Force/NASA AFTI/F-16 incorporates an advanced digital fly-by-wire control system and canard surfaces for implementation of advance combat control modes. The Automatic Maneuvering Attack System (AMAS) phase of the program was initiated in 1984 and will be completed during 1985. An AFTI/F-111 was modified with a Mission Adaptive Wing (MAW) which will demonstrate the aerodynamic performance improvements of a supercritical wing which uses smooth leading-and trailing-edge devices to assume many shapes for optimum performance over a wide operating envelope. The flight research program will begin in the first quarter of 1985.

F-15 Highly Integrated Digital Engine Control (HIDEC). The cooperative NASA/Air Force/Industry HIDEC activity is a flight research experiment to develop the technology required for the beneficial interaction of engine and flight controls. Modifications of an F-15 aircraft were completed in 1984 and the flight research program initiated. The automatic adjustment of engine operating parameters, based on flight conditions, is expected to double the excess supersonic thrust of the modified aircraft as compared to a standard F-15.

Oblique Wing Research Airplane. This joint NASA/Navy activity consists of the design, fabrication, and flight research testing of a composite, aeroelastically tailored high-aspect-ratio oblique wing aircraft at transonic and supersonic flight conditions. The oblique wing concept, conceived by R. T. Jones of NASA, offers potential performance benefits for a variety of military and civil missions. A Request for Proposals was issued in 1984 for the preliminary design of the research airplane, and the flight research program is planned to begin in early 1989.

X-29A Forward Swept Wing Flight Demonstrator. The X-29A program, funded by the Defense Advanced Research Projects Agency (DARPA), achieved several major program milestones in 1984. The flight demonstrator successfully accomplished high-speed taxi tests and was relocated to NASA's Dryden Flight Research Facility to undergo contractor functional flight testing. NASA and Air Force test pilots will participate jointly in the flight envelope expansion of this revolutionary aircraft concept.

RSRA/X-Wing Rotor Flight Demonstration. At DARPA's request, NASA is managing and supporting a program to develop and flight test the X-Wing Rotor concept on one of the two NASA/Army Rotor Systems Research Aircraft (RSRA). In 1984 the helicopter version of the RSRA was modified to accept the unique X-Wing rotor. The compound helicopter RSRA, which includes auxillary wings and propulsion, was flown in a rotorless, fixed-wing mode to clear the flight test envelope for the X-Wing rotor. Supporting research and technology conducted by NASA included wind tunnel investigations and piloted simulations to study the X-Wing rotor characteristics.



The NASA/Army Rotor Systems Research Aircraft (RSRA), already flown as a helicopter and a compound helicopter/airplane, is shown taking off on its maiden flight as an airplane. It is designed to test new rotor systems that may be flown on the helicopter of the future. Testing is done at NASA Ames Dryden Flight Research Facility, Edwards, CA.

Convertible Engine. The first full-scale testing of the unique "convertible" engine was completed successfully, and the feasibility of the concept was demonstrated. A TF-34 turbo-fan engine was modified to provide turbo-shaft power to drive a rotor/propeller or turbofan power for direct thrust propulsion. Potential application of this powerplant includes advanced military vehicles such as the X-Wing, Tilt Fan, and Folded Tilt Rotor concepts.

Tilt Rotor/JVX Aircraft Support. NASA's unique research facilities are providing essential data to the Joint Services Vertical Lift Aircraft (JVX) program. Scale-model-wind-tunnel-powered spin tests were completed at NASA/s Langley Research Center. The Vertical Motion Simulator at NASA's Ames Research Center was used in two design and development tests to validate the JVX math model and evaluate the flight control system characteristics. In addition, testing was completed at the Ames Outdoor Aerodynamic Research Facility on the XV-15 blades, a scale version of the JVX blades, and the Advanced Technology Blades.

Safety and Efficiency in Air Transportation

NASA and the FAA are closely coordinating research activities to provide a safer, more efficient air transportation system for the nation.

Aviation Safety. NASA has continued to advance technologies which enhance aviation safety. Direct lightning strikes to the Langley F-106B research aircraft raised the total to 611 strikes in the five year program. The characterization of atmospheric lightning is being used by DoD and NASA to design new lightning protection concepts for advanced aircraft systems and structures. Wind shear data collected in the interagency doppler radar measurement program in Denver has been applied to the NASA Ames Boeing 727 simulator. This wind shear model is assisting FAA, airlines and aircraft manufacturers in training pilots to cope with this recurring hazard during inadvertent penetrations. At the Lewis Research Center, icing research focused on the correlation of inflight data, obtained on the Lewis Twin Otter, with computer analyses and wind tunnel tests conducted in the Lewis Icing Research Tunnel.

In a joint activity with the FAA, NASA completed the development of advanced, lightweight, fireworthy materials to reduce the threat of fire in aircraft cabins. The FAA accepted the Ames fire blocking layer technology seat cushion concept as the technical basis for rulemaking. In addition, Ames completed development of cabin interior wall panels which have demonstrated a fourfold increase in occupant survival time.

In a major research program, the remotely controlled impact of civil jet transport was successfully accomplished at the NASA Dryden Flight Research Facility. This program evaluated the anti-misting kerosene safety fuel, crashworthy passenger and flight crew seats, and measured structural loads. The results of this test will assist the FAA in implementing additional safety features for civil transport aircraft.

Advanced Transport Operating System (ATOPS). An activity is underway to investigate extending the concept of automatic flight to rollout and turnoff for reduced runway occupancy times during normal and adverse weather conditions. Using a buried magnetic cable, the system has been tested with ground vehicles. Additional experiments will focus on exit design and location, touchdown dispersion, passenger acceptance, and cockpit displays.

Department of Defense

In cooperation with NASA and other Federal Agencies, the Department of Defense (DoD) continues to provide for the security of the United States and its allies by advancing the effectiveness and capabilities of its national resources in communications, navigation, surveillance, aeronautics and strategic defense. During 1984, the DoD initiated plans to acquire a limited number of expendable launch vehicles to complement the Space Transportation System and the Air Force began final preparations for a first launch of the Space Shuttle, in early 1986, from the West Coast Shuttle launch and landing facilities at Vandenberg AFB. The complementary expendable launch vehicles and the new facilities support the President's National Space Policy for assured access to space.

Recognizing that space based command, control, and communication capabilities are crucial to the deterrence and containment of hostilities, efforts to increase the survivability, autonomy, performance, reliability and life of satellites continued during 1984. Also, the Global Positioning System, which will provide precise geodetic positions for military and civilian uses, has produced test results that meet or exceed operational requirements.

The Naval Space Command, which was established in 1983 to consolidate Navy space activities, has assumed operational command of various space systems including the Navy Astronautics Group, Naval Space Surveillance System, Fleet Satellite Communications System, and TRANSIT/NOVA navigation satellite system.

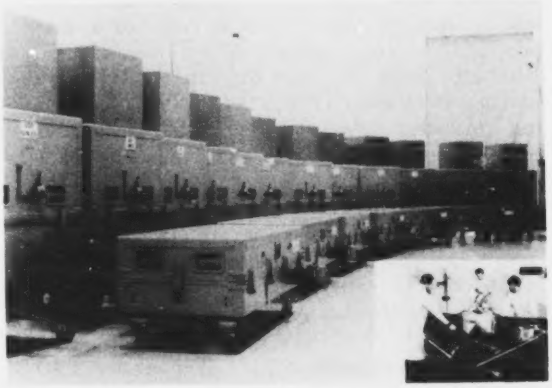
The Strategic Defense Initiative, which began in 1983, has progressed to the definition of five major areas requiring extensive research on key technologies so that informed decisions can be made in the 1990s concerning the possible deployment of defensive systems.

Space Activities

Military Satellite Communications

MILSATCOM. Space based communications systems continue to be reponsive to the needs of command and support forces of the commanders-in-chief, military services and agencies, strategic and tactical nuclear forces, and strategic and tactical conventional forces. The rapidly evolving uncertainties of the world situation and the increasing destructiveness of weapons have made rapid, reliable communications a crucial element in the deterrence and containment of hostilities. Military Satellite Communications (MILSATCOM) meets this challenge by providing nearly instantaneous links between decision makers and forces, deployed worldwide. MILSATCOM uses coordinated systems of specialized satellites and ground terminals to provide reliable and survivable communications to strategic and tactical forces over the full range of conflict and national emergencies.

The development of the MILSATCOM systems has been an evolutionary process. Older systems are constantly improved while new ones are entering the inventory. During 1984, military satellite communications links depended primarily on the Defense Satellite Communications System (DSCS), the Fleet Satellite Communications System (FLTSATCOM), and selected commercial SATCOM circuits. The strategic and tactical nuclear-capable forces also were served by



Lined up and ready for space—a dozen U.S. Navy Transit navigation satellites designed to provide accurate position fixes anywhere in the world, day or night in any weather. With each launch, one satellite will be kept in orbital "storage" to maintain the life of the Navy's Strategic Systems through 1992. The system provides navigation services for thousands of commercial ships equipped with receivers.

the Air Force Satellite Communications System (AFSATCOM), which uses additional transponder packages on FLTSATCOM, the Satellite Data Systems (SDS), and other host satellites. Full operational capability for the AFSATCOM system was achieved in 1984. In the future, strategic and tactical satellite communications will depend on DSCS, Milstar, and follow-on ultra high frequency (UHF) satellite systems.

Defense Satellite Communications System (DSCS). The DSCS segment, which presently operates with three DSCS Phase II and one DSCS Phase III satellites, continues to serve the needs of the command and support forces for long haul, moderate-to-high data rate communications. This super high frequency (SHF) service is being provided to a growing number of stationary and mobile terminals. To ensure a robust control capability for the worldwide DSCS system, a total of five fixed DSCS Operations Centers (DSCSOC) and as many as six mobile DSCS control assets are planned for deployment. The Army is responsible for satisfying ground subsystem requirements for DSCS and a second Operations Center is now operational at Ft. Detrick, Maryland. This center has control responsibility for the Atlantic DSCS area.

Efforts continue to procure, install, and activate new digital communications subsystems and anti-jam equipment to provide a secure, reliable, and survivable worldwide command, control, and communications capability. Four AN/MSQ-114 terminals approved for use and operation with the DSCS III control subsystem were accepted and deployed to the field for tactical use. Final acceptance testing of the AN/TSC-85A multi-channel and the AN/TSC-93A single channel tactical terminals was initiated. The Navy's SHF SATCOM terminal, AN/WSC-6 with the OM-55 modem, will be installed aboard all fleet flagships to provide jam-resistant communications for commanders of numbered fleets. The first flagship installations were initiated in October 1984. The AN/WSC-6 also is being installed aboard 12 surface-towed array surveillance systems (SURTASS) ships with the MD-1030A modem.

To provide increased capabilities and more survivable communications, the ground terminals and control elements of DSCS continue to be upgraded and expanded. The delivery of 39 AN/GSC-52 medium terminals is scheduled to begin in the middle of 1985. The upgrade of 21 AN/GSC-39 medium terminals was completed by the end of 1984. During the 1985-86 period, selected DSCS control facilities will receive the Satellite Configuration Control Elements (SCCE) providing an automated means of controlling competing users. Moreover, modernization to improve the capacity and capabilities of the DSCS terminals by the integration of Digital Communications Subsystems continues with some forty sites scheduled for modernization between 1985 and 1988.

Predicated on the need to achieve an evolutionary transition from a limited manual capability to a vastly more efficient semi-automated system control, other procurements are planned to occur by 1987. Included are Frequency Division Multiple Access Control Subsystems which monitor network terminal performance and relay information to major control terminals, Smart Multi-Circuit Terminals, and the Ground Mobile Forces Control Link. These components in the DSCS operations control system will provide an enhanced capability to monitor, control and reconfigure the DSCS to support communications vital to the national security under stressed and unstressed conditions.

Milstar. Development of the EHF Milstar satellite continued under the managment of the Air Force Joint Milstar Program Office. Full-scale development activities were performed by the Lockheed Missile and Space Corporation, Sunnyvale, California. Half of the spacecraft subsystem Preliminary Design Reviews were completed in 1984. The Air Force has responsibility for developing Milstar terminals for all airborne platforms. The Navy is developing shipboard terminals; and the Army will acquire the Single Channel Objective Tactical Terminal (SCOTT) to support the National Command Authorities, Joint Chiefs of Staff, and general terminal requirements of the Services. Advanced development of SCOTT has been completed. By the end of 1984, most of the Air Force Phase I terminal development work was completed; and the Air Force will select a primary Phase II Full Scale Development contractor.

Fleet Satellite Communications System (FLTSATCOM). The Navy managed UHF satellite communications systems continued to provide worldwide coverage between latitudes 70 degrees north and 70 degrees south to strategic and tactical forces including the Navy, Commanders-in-Chief of the Unified and Specified Commands, the National Command Authority and other high priority users. UHF SATCOM is the primary military communications link for strategic and tactical mobile forces and is the backbone of day-to-day command, control and communications to forces afloat. It consists of three satellite constellations: FLTSAT, GAPFILLER AND LEASAT (GAPFILLER'S replacement). GAPFILLER is a three-satellite system which has provided coverage of three ocean areas since 1976. A leased package on the Marisat satellites, GAPFILLER has provided 25 spacecraft-years of service and will be replaced by the four-satellite LEASAT constellation during FY 85. LEASAT is under contract to Hughes to provide leased services for five years and will become fully operational by October 1985. Two satellites of this system were launched from the Space Shuttle in 1984; and the remaining two are expected to be launched during February and July 1985, respectively. The four satellites of the FLTSAT constellation were launched

February 1978 through October 1980 and are expected to provide service until 1988. Continued service will be provided by launching the FLTSAT 6, 7, and 8 replacement satellites in the 1985-87 time period.

Follow-on evaluation of the Army UHF manpack and vehicular mounted satellite terminals, the AN/PSC-3 and VSC-7, was completed and distribution of these terminals to special operations forces began in 1984. Operating with the AFSATCOM and FLTSATCOM satellites, these terminals will provide Army tactical commanders a new and highly reliable capability to satisfy critical command, control, and intelligence communications in a secure mode.

The need for DoD UHF SATCOM capability will continue at least into the 21st century. FLTSATCOM/LEASATCOM will provide service until the early 1990s. Plans are underway for a Follow-On UHF Space Segment, consisting of high capacity satellites, that will be deployed in late 1991 or early 1992.

Army Satellite Communications Activities. The Army Satellite Communications Program provides funds for ground terminal development and is the framework for the procurement of ground terminals by all the Armed Services and other Government agencies. Satellite ground terminals are developed in response to validated requirements of the Joint Chiefs of Staff to replace or supplement existing communicaitons systems which do not have the capability or survivability required on the modern battlefield. This program supports command and control requirements of the tactical and strategic commanders, as well as those of the National Command Authorities and the Defense Communications System for rapid, reliable, and effective communications.

Tactical satellite communication links with ground forces are rapidly becoming an integral part of command, control, and communications on the battlefield. Production of super high frequency AN/TSC-85A and AN/TSC-93A multi-channel tactical terminals will improve anti-jam and traffic handling capabilities. This improvement will upgrade interoperability with the AN/TSC-94 and AN/TSC-100 terminals. Follow-on production contracts for the ultra high frequency manpacked and vehicular mounted AN PSC-3 and AN/VSC-7 satellite terminals will be initiated in 1985.

Navigation and Geodesy

Global Positioning System. Procurement of operational satellites for the Navstar Global Positioning System completed its third year under a multi-year 28 spacecraft contract. The first operational launch is scheduled for the last quater of 1986 with full operational capability planned by the end of 1988. Development of the GPS receivers continued in 1984 with the two user equipment contractors: Rockwell/Collins and Magnavox. The test results obtained from a variety of host vehicles (M-60, F-16, B-52, UH-60, submarines, and carriers) indicate that overall system performance is meeting or exceeding requirements. In addition, the Defense Mapping Agency continued acceptance testing of GPS geodetic receivers. These units will be phased into operation in 1985.

Developmental GPS satellites 9 and 10 were successfully launched in 1984, leaving one remaining satellite to be launched. The ground control segment of the system has been deployed and is currently undergoing final testing. Although the current control center is located at Vandenberg, AFB, California, it will be transferred to the Consolidated Space Operations Center (CSOC) at Falcon AFS, Colorado in 1986.

Geodetic and Geophysical Satellite. The Navy's geodetic and geophysical satellite (GEOSAT) is scheduled to be launched in February 1985 to determine a precise marine geoid by measuring accurately small variations in the height of the ocean surface. This precision is necessary to support the increased accuracy requirements of the Trident II (D-5) missile. After the geoid measurements are completed about 19 months following launch, the satellite will be repositioned into an exact repeat orbit to optimize oceanographic measurements of wave height and surface wind speed and to locate ocean fronts and eddies. Spacecraft testing was completed at the end of 1984, and spacecraft integration with the Atlas E launch vehicle is scheduled to begin in January 1985 at Vandenberg AFB, California.

Meteorology and Oceanography

Navy Remote Ocean Sensing System. The Navy's Remote Ocean Sensing System (N-ROSS) satellite is designed to measure ocean surface winds, sea surface temperatures, ocean fronts and eddies, polar ice conditions, atmospheric water vapor and significant wave heights. The sensor suit of the N-ROSS derives its heritage from the SEASAT, NIMBUS, GEOSAT, and NOSS satellite projects. NASA will build the scatterometer sensor (ocean surface winds), the Air Force will manage the launch, command and control functions, and the Navy will process the N-ROSS data at the Fleet Numerical Oceanography Center at Monterey, California. After processing, the data will be provided to the National Oceanographic and Atmospheric Administration (NOAA) for distribution to other federal agencies, private industry, and the academic community. Current plans are to launch this satellite in June of 1989.

In October 1984 a Navy Oceanographer flew aboard Shuttle mission STS 41-G to view and record discreet ocean phenomena from low earth orbit. The initial examination of data and observations from this flight point to new discoveries in ocean structure. The Navy will continue to work with NASA to exploit fully the unique opportunities afforded by the direct observation of oceanic parameters from space by man.

Surveillance and Warning

Early warning satellites provide warning of ballistic missile attacks to the National Command Authorities, Strategic Air Command, and North American Aerospace Defense Command. Additionally, the DoD is developing cruise missile surveillance techniques which may lead to a warning system similar to that for ballistic missiles. The purpose is to investigate the feasibility of cruise missile detection and tracking technology from space platforms, develop the key technologies required, evaluate their performance, and provide a confident basis for any future decision on full scale development. The Air Force has initiated technology concept assessments and infrared phenomonology measurements associated with cruise missile flights against low contrast earth backgrounds. Included will be mission data analysis of the Teal Ruby program, a joint Air Force and DARPA on-orbit test to demonstrate infrared detection of air-breathing vehicles. When launched, the Teal Ruby program will provide the initial demonstration of a space-based infrared sensor designed to acquire, identify, and track aircraft and cruise missiles. Specifically, Teal Ruby will collect measurements against low intensity signatures such as those of strategic and tactical aircraft and cruise missiles. These data are vital for development of a space based, wide area surveillance system. In 1984, the Teal Ruby flight sensor construction was completed; and it is currently undergoing integration testing. Also in 1984, the spacecraft was taken to Vandenberg AFB for a totally successful open-loop compatibility check with the remote satellite tracking station there.

Antisatellite (ASAT) Program. The ASAT is an air-launched antisatellite missile system consisting of a modified Short Range Attack Missile (SRAM) first stage, a modified Altair second stage, and a miniature warhead. ASATs will be launched from designated air defense F-15s. The primary purposes of a U.S. ASAT capability are to deter threats to space systems of the United States and its allies and, if necessary, to deny any adversary the use of space-based systems that provide support to hostile military forces. Captive-carry flight tests began in December 1982; and a point-in-space flight test was completed successfully in January 1984. Tests against instrumented satellites designed to measure the performance of the ASAT missile are planned for fiscal year 1985.

Strategic Defense Initiative. U.S. research and technology projects on strategic defenses against ballistic missiles have been consolidated under the Strategic Defense Initiative Organization which is responsible for directing the applicable programs of the Army, Navy, Air Force, Defense Nuclear Agency, Department of Energy, and Defense Advanced Research Projects Agency. The Strategic Defense Initative program goal is to conduct research on key technologies so that informed decisions can be made in the 1900s on whether to develop and deploy defensive systems.

The Strategic Defense Initiative research is divided into the following five major program elements.

The first of these, Surveillance, Acquistion, Tracking, and Kill Assessment (SATKA), is chartered to conduct research on the technologies needed to detect, identify, locate, and track ballistic missiles or their components during the boost, mid-course, and terminal phases of a ballistic missile trajectory.

The next consolidates the directed energy weapons projects, directing research into the four general classes of directed energy weapons applicable to missile defense: space based lasers, ground based lasers, X-ray lasers, and particle beams.

The third program element has to do with research on kinetic energy weapons designed to destroy ballistic missiles or their components by direct impact. Research is focused here on "smart bullets" which could be fired from the ground or space. An example of kinetic energy weapons research is the U.S. Army's successful demonstration last June of the technologies needed to intercept and destroy a ballistic missile warhead in space using non-nuclear techniques.

One of the most critical program elements is Battle Management and Command Control, and Communications Systems. The research goal is to determine how positive command and control might be structured for a defensive system. During 1984, ten contracts were awarded for the study of strategic defense architecture options.

The fifth and final program element of the Strategic Defense Initiative is Survivability, Lethality, and Key Technologies. Here, research is being focused on the problems of space electrical power, launch vehicle requirements, and the critical areas of lethal capability of ballistic missiles and defensive system survivability.

This approach provides a coordinated and focused research program that will permit decision makers, in the early 1990s, to make informed choices on whether to develop and deploy defenses against the ballistic missile threat to the United States and our allies.

Space Transporation

Expendable Launch Vehicles (ELVs). During 1984, DoD launched eight Titan III and four Atlas E vehicles, in addition to two Scout vehicles and one Delta launched for DoD by NASA. In support of the President's National Space Policy for assured access to space (August 1984), DoD initiated plans to acquire a limited number of ELVs for launch during the 1988-1992 period. The ELVs will be used as a complement to the Space Shuttle; and will be capable of launching Shuttle-class, DoD payloads which are critical to the nation's security.

Space Shuttle. The National Aeronautics and Space Administration and DoD are involved in developing and operating the Space Shuttle. NASA has the development and operation responsibilities for the Space Shuttle vehicles. These include the East Coast Shuttle launch and landing facilities at Kennedy Space Center, Florida, and the Mission Control Center at Johnson Space Center, Texas. DoD's responsibilities for the Shuttle include development of the inertial upper stage (IUS) and operation of the West Coast Shuttle launch and landing facilities at Vandenberg AFB, California. The Air Force also is funding modifications of existing NASA facilities and equipment to accommodate classified operations at Johnson, Kennedy, and Goddard Space Centers. Construction of the major facilities at Vandenberg is essentially complete, and installation of support equipment is well underway. Preparation has begun for a first launch early in 1986. Vandenberg will provide a Shuttle capability to launch satellites into polar orbit which cannot be reached from the Eastern launch site at Kennedy.

Upper Stage Programs. Space Shuttle upper stages include the commercial PAM-D and PAM-A which can carry 450 to 1,400 kilograms (kg) to geosynchronous orbit; the Air Force IUS which can carry 2,300 kg to geosynchronous orbit; and the joint NASA-Air Force Centaur which can carry 4,500 kg to geosynchronous oribt. In October 1983, the Air Force awarded a multiyear contract for 28 PAM-D IIs, a more powerful version of the PAM-D. These vehicles will support the Navstar Global Positioning System.

Following the first launch of the IUS on a Titan III in October 1982, successfully placing a DSCS II satellite in orbit, the first Shuttle IUS launched the Tracking and Data Relay Satellite TDRS 1 in 1983. Because of a malfunction in the second stage motor of the IUS, the satellite was placed in an elliptical orbit. Subsequent orbit adjustments by the TDRS propulsion system moved the satellite into its proper orbit. A recovery plan to correct the motor problem was established in 1984, and IUS flights are expected to resume in early 1985.

The Joint Centaur program will develop two configurations. The first is the Centaur G which will be six meters long and have a 4,500-kg-to-geosynchronous capability; it will be the basic configuration for common use by NASA and DoD. The second configuration will be a stretched Centaur G with increased performance for the NASA Galileo and Ulysses missions in 1986.

Advanced Spacecraft Technology. The Air Force continues with an advanced spacecraft technology program. The primary objectives are to increase satellite survivability, autonomy, performance reliability, and lifetime. Secondary objectives are to employ lighter, less complex, and more economical units than currently exist. The focus is in four major areas: computers and electronics, space guidance, power, and technology planning. In 1984, the space-qualified 16k RAM chip development was completed and commercial production was initiated. Development of larger, more capable, hardened components was started. The satellite autonomy project completed its two year study effort and a preliminary design review was conducted. Development of a high efficiency solar panel for testing in a high radiation environment was completed.

Space Test Program. The Space Test Program (STP) provided space flights for 14 experiments on various missions during 1984. STP had 5 experiments aboard the NASA Long Duration Exposure Facility (LDEF) launched from STS-41C on 6 April 1984. These experiments will study space environment and background effects on new materials for use in future DoD space systems. NASA plans to recover LDEF on STS 51-D in 1986. In June 1984, two experiments measuring aerosols and performing spectrometry were flown on a host spacecraft. Seven Quick Response Shuttle type payloads were flown on six Space Shuttle flights. These experiments were flown in NASA Get-Away Special canisters in the Shuttle payload bay or were flown and performed on the Shuttle aft/mid-flight deck by the astronauts.

NASA and STP completed agreements to work on the Combined Release and Radiation Effects Satellite (CRRES) mission. This joint program will develop and launch from the Shuttle a free-flying spacecraft to perform a NASA chemical release mission during its three month flight profile in low earth orbit and then boost itself into a high-altitude, elliptic orbit for a DoD mission to evaluate the performance of advanced microelectronic components in a high-radiation space environment. The Air Force will fund the CRRES spacecraft, and NASA will fund the Shuttle integration and launch the spacecraft. Data from both CRRES missions will support development of future DoD and NASA spacecraft.

Aeronautical Activities

Fixed-Wing Programs

Bomber Development. The first production B-1B, produced by Rockwell International, was rolled out on 4 September 1984. Its first flight lasted three hours and was conducted on 18 October 1984. Designated B-1B number one, this aircraft will join the B-1 test progam at Edwards AFB, California. To date, the B-1 test program has flown more than 2,150 flight-test hours. The B-1A number four, which appeared at the Farnborough Air Show in September 1982, began its portion of the flight testing program in July 1984. This B-1A prototype, being modified with the complete B-1B offensive and defensive systems, is conducting heavyweight buildup tests, offensive and defensive avionics tests, and terrain-following evaluations. B-1A number two, a fully instrumented prototype, conducted test and evaluation flights from March 1984 until its loss on 29 August 1984. Its test accomplishments included weapon carriage and separation, vibration and acoustics, and stability and control tests. The first production B-1B will expand upon the testing begun by B-1A number two and supplement the testing done with B-1A number four.

Advanced Tactical Fighter (ATF). The ATF program is developing the USAF's next-generation air superiority fighter. It is a follow-on to the F-15, with enhanced capabilities to support the offensive counterair role. Enhancements in performance, survivability, and support are designed to provide new tactical capabilities to defeat the Soviet threat in the 1990s and beyond. The ATF Concept Definition Phase was completed during the summer of 1984. Boeing Aerospace Corporation, General Dynamics Corporation, Grumman Aircraft Company, McDonnell Douglas Aircraft Company, Northrop Corporation, Rockwell International, and Lockheed all participated in the concept development studies. The Air Force will continue evolving the ATF design with competitive demonstration and validation of ATF concepts and key technologies starting in 1985. The Joint Advanced Fighter Engine, another part of the ATF development program, began in September 1983 with the award of competitive engine development contracts to the Pratt & Whitney Aircraft Group and the General Electric Company. Both contractors are building engine components, full-scale and flightweight engines, and nozzles for testing. Engine test-stand operations will begin in the summer of 1985. The program objective is to have a mature engine design when the ATF enters full-scale development during the late 1980s. Initial Operational Capability is planned for the mid-1990s.

C-5. The wing modification production program for the C-5A fleet proceeded on schedule in 1984, with modifications completed on 30 aircraft. Modification of the entire fleet of 77 aircraft is scheduled to be completed by July 1987. This modification will permit the C-5A to attain full mission capability and will extend aircraft service life by 30,000 flight hours. The new production program for the C-5B will use a wing of the same basic design. The projected service life of the C-5B also is 30,000 flight hours. Both the C-5A and C-5B are expected to be operable well into the next century. The fixed-price contract for production of 50 new C-5B aircraft was awarded in late 1982. The program is on schedule, with the first aircraft to be delivered in December 1985. The C-5A wing modification production program is managed by the Air Force Logistics Command, and the C-5B production program is under the Air Force Systems Command.

C-17. The C-17 transport aircraft, designed to meet U.S. airlift needs into the 21st century, will provide the final increment of intertheater airlift capability to reach the minimum specified by the Congressionally Mandated Mobility Study, replace the capability lost from retiring early model C-130s and some C-141s in the 1990s and provide needed modernization of airlift force structure. The aircraft will combine FAA-certified engines with the powered lift technology originally demonstrated on the YC-15 Advanced Medium Short Takeoff and Landing (AMST) prototype. Congress approved the Air Force fiscal 1985 request for $123.3 million to begin full-scale development. This development effort will continue through 1986, leading to a production start in 1988 and an initial operational capability by 1992.

T-46. The T-46 will replace the aging and operationally deficient T-37 trainer aircraft which currently is used in Air Force pilot training, navigator training, and Strategic Air Command's copilot enrichment program. The prime contractors, Fairchild Republic Company and Garrett Turbine Engine Company, completed their critical design reviews and proceeded in 1984 with the fabrication of two flight test aircraft in preparation for a first flight in April 1985. Production deliveries will begin in April 1986, and the first pilot class using the T-46 will start training in January 1988.

T-45A. In October 1984, the Secretary of Defense authorized development of a fully integrated Naval Aviator training system (aircraft, simulator, and academic equipment) to replace the capability currently provided by the T-2C (intermediate) and TA-4J (advanced) jet training aircraft. Replacement need is underscored by aircraft shortfalls and escalating ownership costs. The T-45A, carrier capable derivative of the British Aerospace Hawk aircraft, and the associated ground training subsystems will be developed by the McDonnell Douglas Corporation. Aircraft first flight is scheduled for 1987 with production deliveries to begin in 1989. Initial Operational Capability for the system is planned for 1990; and production of 300 aircraft, 32 simulators and associated training equipment will continue through 1995. The T-45As will require 40 percent fewer hardware and manpower resources than are currently employed.

Cruise Missile Programs

Air Launched Cruise Missile (ALCM). The ALCM, a key element in the Triad of U.S. land, air and sea forces, provides the bomber force with weapon accuracy, flexible routing and targeting, reduced exposure to enemy defenses, and saturation of defenses. Production started in 1980. The B-52G aircraft carry 12 ALCMs loaded on two external pylons, while still retaining the internal capability of carrying Short Range Attack Missiles and gravity weapons. Beginning in fiscal 1986, ALCMs also will be loaded externally on B-52H aircraft. Future plans include internal loading of cruise missiles on B-52Hs for a total of 20 missiles per aircraft. The B-1B also will be capable of carrying cruise missiles. A total of 1715 missiles are to be delivered to the Strategic Air Command. At the end of 1984, five B-52G aircraft squadrons were operational with the ALCM; and the Strategic Air Command was conducting follow-on operational test and evaluation.

Ground Launched Cruise Missile (GLCM). The Air Force GLCM possesses high prelaunch and enroute survivability, 2500 kilometer range, and high accuracy which enhances the NATO deterrent nuclear force. The deployment plan, unless altered by arms talks, calls for 464 missiles based in five countries by 1988.

GLCM deployment and testing continues on schedule. After reaching its initial operational capability in December 1983 at Greenham Common, United Kingdom, operational capability was achieved in March 1984 at Comiso, Italy. Follow-on Operational Test and Evaluation (FOT&E) Phase I was completed in June 1984, demonstrating that the GLCM weapon system can perform its mission effectively in an operational environment. FOT&E Phase II was initiated in July 1984 and will continue to gather data from ground testing, communication testing, and flight testing through December 1985.

Helicopter Programs

APACHE, (AH-64), Advanced Attack Helicopter. The APACHE is the Army's top aviation procurement program and will provide a lethal anti-tank capability 24 hours a day. The APACHE, armed with a laser guided HELLFIRE missile, provides significant improvements over existing systems in tank killing ability. The first production lot of 11 aircraft has been delivered to the Army. Two of those aircraft were in flight test in 1984 to verify successful transition to production. Initial pilot and mechanic training has begun and the AH-64 will be deployed at Fort Hood, Texas, early in 1986.

CH-47 Modernization. The Initial Operational Capability for the CH-47D was met on schedule at Fort Campbell, Kentucky, in February 1984. Deployment of the aircraft was highly successful, achieving an operational readiness rate of 78 percent against an Army standard of 70 percent. A production contract to modernize 36 additional CH-47 helicopters was awarded in June 1984. A contract to modernize 48 CH-47 helicopters is planned for fiscal 85, the first year of a 5-year contract. A total of 436 CH-47s will be modernized.

HH-60A Night Hawk. The Air Force has begun to flight test its version of the Army's UH-60A, which is designed for combat rescue operations. The Air Force is modifying the basic UH-60A airframe for extended range and increased hover performance while adding improved avionics for long range, low level, precision navigation. The program has been restructured from a 155 aircraft, $2.8 billion program to a more affordable 90 aircraft, $1 billion program. Production is scheduled to begin in 1986 with initial operational capability in 1988.

V/STOL Programs

Joint Service Advanced Vertical Lift Aircraft (JVX). The JVX is under development as a vertical lift aircraft using advanced technology to provide the USMC, USN, USAF, and USA with a self-deployable, multi-mission Vertical/Short Takeoff and Landing (V/STOL) capability for the 1990s and beyond. The JVX weapon system will be capable of satisfying various operational requirements, such as Marine Corps assault vertical lift, Navy combat search and rescue, Air Force special operations, and Army medium cargo assault lift.

A 23-month Preliminary Design Phase began in April 1983 and is a two-part program leading to a full-scale development decision in mid-1985. The first part of the Preliminary Design Phase is to substantiate JVX design capability, discover potential problems early in the program to reduce technical and schedule risks, and then conduct design trade-off studies among specific operational requirements, design criteria and configuration variations to obtain the most mission-effective system.

The second phase of the Preliminary Design effort, began in May 1984 to protect 1991 deliveries by concentrating on critical areas to reduce program risk during Full Scale Development. This phase builds upon the wind tunnel testing and trade studies accomplished during the first phase. Three important wind tunnel tests were completed: powered model testing, aeroelasticity testing, and large scale rotor performance testing. The results of these tests will lead to detail design of the Ground Test Vehicle, which is critical to a first flight in early 1988.

The Navy has formed a panel of high level civilians and military officers from all major elements of the Navy to investigate the potential for JVX to accomplish other missions. The main objective of the panel is to identify and study mission applications that look promising for JVX, without requiring major airframe changes. The Air Force also is investigating other potential mission applications for JVX.

Aeronautical Research and Development

X-29 Advanced Technology Demonstrator. The X-29, the first X-series aircraft in over a decade, will demonstrate and evaluate eight advanced high risk, and high payoff technologies. The exploitation of these technologies will advance future fighter performance and reduce the time, risk, and cost of future developments. This joint DARPA-NASA-USAF technology development program will expand significantly earlier advanced composite research, aerodynamic and structural analytical design methods, digital flight control system design techniques, system integration experience, and test and evaluation capabilities. Following extensive ground testing and simulation, the aircraft was shipped to the Dryden

Flight Research Facility at Edwards AFB, California, in October 1984 and prepared for flight testing. Evaluation of the flight test program, jointly by government and industry, began in late 1984. The initial flight was made December 14 and lasted for nearly one hour. Strong emphasis will be placed on achieving the rapid transfer of test results to corporate and government users through the DARPA X-29 Future Applications Committee, and on validating advanced concepts to provide new viable design options and performance improvements for future fighters.

Advanced Fighter Technology Integration (AFTI). The Air Force AFTI test aircraft is a modified F-16 that integrates an advanced digital flight control system with canard control surfaces to achieve increased agility. Completed in August 1983, the first phase flight test validated the digital control system. The second phase is evaluating an automated maneuvering attack system. After Phase I, the test aircraft was returned to the General Dynamics factory in Fort Worth, Texas, where it was modified with an advanced fire control system and provisions for a new infrared sensor and tracker. Flight testing for the second phase began at Edwards AFB, California, in September 1984. The infrared sensor and tracker, being built by the Westinghouse Corporation of Baltimore, Maryland, will be installed in the AFTI test aircraft at Edwards AFB early in 1985. The fully integrated system provides for highly accurate, maneuvering attack against ground targets at very low altitude, as well as for improved air-to-air effectiveness. Technologies demonstrated in the AFTI program will be used to improve the performance of future aircraft such as the Advanced Tactical Fighter.

X-Wing. This concept is a major innovation in vertical takeoff and landing (VTOL) aircraft design. It combines the vertical lifting efficiency of a helicopter with the speed, range, and altitude performance of a transonic fixed-wing aircraft. The X-Wing operates as a rigid rotor helicopter that uses circulation control instead of blade pitching for lift and control. When aloft, the X-Wing aircraft converts to a fixed-wing configuration in forward flight. With the rotor stopped and the fixed blades swept both forward and aft, the aircraft will be capable of high transonic speeds. During fiscal 84, the joint DARPA/NASA X-Wing program passed a major milestone at its Critical Design Review. The major X-Wing components approved are: the 56 ft diameter rotor and bearingless hub, the pneumatic valving system for blade cyclic lift control, a high torque clutch and brake, and a highly advanced digital fly-by-wire control system with provisions for active rotor stabilization and high harmonic vibration suppression. The winged version of the rotor system research aircraft (RSRA) also was flight tested during this period.

In fiscal 85, the full-scale rotor system, with all drive components will be fabricated and tested. The flight control computer will be tested in a full vehicle simulation laboratory which includes all flight hardware. Following completion of these tests, the RSRA airframe will be integrated with these and other subsystems and readied for integrated vehicle ground testing in late fiscal 85. Flight testing of the vehicle is planned for early fiscal 86.

Oblique Wing Research Aircraft (OWRA). The Navy and NASA have joined in an Oblique Wing Research Aircraft (OWRA) program to investigate the unique aerodynamic, structural, and required control systems for various aircraft missions. Under the joint OWRA program, an oblique wing and associated systems will be designed, fabricated, installed, and flight-tested on the NASA F-8 Digital Fly-By-Wire (DFBW) research aircraft. The F-8 DFBW aircraft provides a unique research capability because its general configuration allows easy modification of the oblique wing and has a readily modified, highly flexible flight control system with fully developed ground based control facilities.

The program will involve four contracted phases. Phase A, which has been completed, was a feasibility study which showed concept viability. Phase B will be a competitive preliminary design phase which will provide the general size and configuration of an aeroelastically tailored, composite oblique wing and corresponding wing assembly, and also will provide necessary details and trades to support the completion of the specifications. Phase C will include the detailed design work, fabrication, aircraft modification, and flight qualification testing. Phase D is the flight test support of the government flight test program.

A successful OWRA program will provide the technology data base necessary for oblique wing concepts to become viable candidates for future Naval aircraft designs. An oblique wing aircraft could increase the Carrier Air Patrol (CAP) radius, thus increasing the intercept range to threatening air-launched missiles and missile platforms, or could increase time on target for ground, surface ship or submarine attack aircraft. In either case, with increased carrier deck loading, due to a decreased spotting factor, more aircraft can be directed at the threat targets.

Command Flight Path Display (CFPD). Investigations continued in 1984 into the Command Flight Path Display system formerly titled Maneuvering Flight Path Display System. In a non-combat environment, the CFPD has demonstrated successfully a new all-weather flight-guidance-display concept for integrating guidance information in a single "highway in the sky" which the pilot follows. Efforts now are being directed to combat maneuvering and simulated missile launch under all-weather conditions. Reference data (altitude, airspeed, weapons, targets, etc.) can be provided on the display in accordance with pilot needs. The system, which requires extensive computational capability to maintain real-time path-guidance, is installed in a fighter combat simulator for verification before flight testing in an F-14 aircraft. Future efforts will be directed to extending its application to helicopter combat maneuvering and low-altitude terrain-following in all weather conditions.

Rotorcraft System Integration Simulator (RSIS). The Army is developing an aviation engineering research simulation capability through a joint development program with NASA. Called the Rotorcraft System Integration Simulator (RSIS), the program will enable the Army and NASA to simulate rotorcraft flight dynamics, thereby providing vital information for the development of helicopters, validating system designs, and producing information for future aircraft improvements. Through the use of the RSIS, the Army will be able to resolve many of the problems associated with developing new or improving rotorcraft, flying qualities, system integration, and weapon system effectiveness. Furthermore, from the aircraft engineering software developed as part of the RSIS program, the Army will develop a software package for potential use in all flight training simulators. Through this joint NASA/Army program, rotary wing development and product improvement will be greatly enhanced. The RSIS demonstration and validation will be completed in fiscal 86; the air combat upgrade will be completed in fiscal 87.

ARTI. The Army has initiated a program entitled Advanced Rotorcraft Technology Integration (ARTI) in support of the full-scale development of a family of light helicopters (LHX) which is currently planned for fiscal 86. Previous research efforts have demonstrated that a highly integrated and automated cockpit could provide the LHX and existing helicopters with numerous desirable operational characteristics. Among these are improved communications and navigation accuracies, reduced target acquisition, weapons system management, and overall pilot workload reduction. The objectives of the ARTI program are the development of the design requirements and system specifications for an Advanced Integrated/Automated Cockpit and associated electronic architecture as applied to the LHX development, and to determine the practicality of a single crew member concept as effected by the rapidly emerging electronic technologies.

Five contracts for ARTI were awarded in December 1983. The initial contracts are for a two year effort which will include LHX mission analysis, cockpit and architecture system design and fabrication, flight simulation, and flight test. These efforts will result in recommended design requirements and system concepts for the LHX FSD.

Microwave Landing System. The Air Force continued its efforts as the lead service for the DoD Microwave Landing System (MLS) program. In 1984, the Air Force issued a directive to initiate acquisition of Tactical MLS equipment and commercial MLS avionics. Studies leading to a DoD decision on military standard MLS avionics in fiscal 86 were started. The DoD continued to work closely with the FAA on Fixed Base MLS acquisitions which are planned for fiscal 87. The August 1983 DoD MLS Implementation Plan was updated in June 1984. The Army avionics program in 1984 centered on modernization and standardization of avionics components and subsystems. Participation continued in the National Microwave Landing System (MLS) and the Tri-Service Tactical MLS. The Army will procure two National MLS systems in 1985 under a Federal Aviation Administration contract for the aviation training center at Ft. Rucker, Alabama. This will provide a smooth transition and insure the Army's ability to continue operation in the civil and NATO aeronautical structure.

Avionics. Other tri-service efforts included the Digital Audio Distribution System (DADS). Source selection for this development effort was completed with two parallel competitive contracts awarded. In another advance development, dual contracts were awarded on the Joint Air Force-Army Integrated Communications, Navigation, Identification Avionics (ICNIA) program. ICNIA will consolidate all the aircraft radio signals into one unit with the use of digital avionics. Extensive efforts continued in 1984 on programs to improve electronics which reduce pilot workloads and enhance combat effectiveness. The development of the Airborne Target Handoff System (THS), which will provide airborne data communications over existing aircraft radios, was completed and successfully demonstrated. This can be applied to the AH-64, AHIP, and LHX helicopters. Other technologies developed and demonstrated included: the ring laser gyro, High Reliability Attitude Heading and Reference System (HRAHRS) for improved performance and navigational capability, the digital map generator for displaying, inputting and updating map information in a tactical mission environment, and Voice Interactive Avionics (VIA) for allowing the pilot to call up selected displays or functions to reduce pilot workload and increase system response. These advances in technology will enhance single crew member capability and allow serious consideration of these options in future helicopters.

Army's Aeronautical Technology Research. The objectives of this program are the expansion of knowledge in varous scientific disciplines and technical areas which then can be exploited to advance aeronautical technologies, resulting in improving the operational effectiveness of helicopters. Technologies and areas of study involved in this program include aerodynamics, structures and propulsion systems, reliability and maintainability, safety and survivability, flight simulation, and ergonomics. This program is a continuing effort which produced the following representative accomplishments in 1984: flight testing a ring fin tail rotor for improving directional control; testing an oil debris detection system; designing rotor hubs made of composite materials for the CH-47 and UH-60 helicopters; achieving a 15 to 1 pressure ratio in an experimental centrifugal compressor; and initiating environmental flight testing of an icing severity level indicator system.

Advanced Composite Airframes. The Army's Advanced Composite Airframe Program (ACAP) is a developmental engineering effort to establish the design data, fabrication approach and test experience needed to facilitate the use of advanced composite materials in building primary and secondary airframe structures for helicopters. Contracts with Bell Helicopter and Sikorsky Aircraft provide a broad base for ACAP development. The Bell ACAP aircraft is using components from their Model 222 commercial helicopter; Sikorsky is using their S-76 commercial helicopter in a similar manner. Such application of composites is expected to reduce airframe acquisition cost by 17 percent and weight by 22 percent, with collateral improvements in ballistic tolerance, reduced radar signatures, and improved repair and maintenance features. The improvements in structural repair and maintenance should result primarily from significant reductions in the number of structural parts and mechanical fasteners.

Sikorsky has completed fabrication of the static test article and flight test vehicle airframes. Laboratory static testing of the full scale test article has been completed and the first flight of all composite airframe occurred on 16 August 1984. Static testing of portions of the Bell airframe was initiated in 1984 with final assembly and flight testing planned for 1985. Analysis of laboratory and flight test data and comparisons of these results with analytical design predictions will be used to substantiate the manufacture and structural integrity of composite airframes.

Advanced Digital-Optical Control System (ADOCS). The objectives of the ADOCS program is the installation of digital-optical flight control systems on the next generation of Army Aircraft, rather than the continued use of mechanical flight control systems. The benefits expected from this effort are: improved aircraft handling characteristics, decreased pilot work load, improved reliability and survivability, reduction in control system weight, and reduced life cycle costs. The preliminary design, detailed design, and modification phases of the program have been accomplished for the UH-60 aircraft. The program is presently in the test and evaluation phase, which is 30 percent complete. Flight testing is planned for early 1985.

Space and Aeronautics Support

Satellite Control Facility (AFSCF). The Air Force controls satellites for the DoD from the Satellite Test Center at Sunnyvale, California, and a worldwide network of seven tracking stations. During 1984, the network supported 21 launches, including 10 DoD and 5 NASA orbited missions and 6 ballistic flight tests.

The Data System Modernization (DSM) program continued its development with operations scheduled to begin at the AFSCF and the Consolidated Space Operations Center (CSOC) in 1986 and 1987, respectively. The new system will form the core data-processing system for this evolving Satellite Control Network. A contract was awarded in June 1984 for the development of the Advanced Remote Tracking Station (ARTS) program. ARTS will replace or refurbish the existing remote tracking stations and complement DSM.

Consolidated Space Operations Center (CSOC). Construction of CSOC facilities continued throughout 1984 at Falcon AFS, Colorado Springs, Colorado. The CSOC buildings were closed in during the fall of 1984 to allow interior work to continue through the winter months. Occupancy of the buildings is planned for October 1985. Contracts for communications systems and the satellite operations complex were awarded in 1984 to provide the operational satellite mission control center, with an additional center to be activated in 1988. Two competitive contracts were awarded in 1984 for definition of the Shuttle Operations and Planning Complex segment. Initial Shuttle operations will begin with an emergency backup recovery capability at CSOC in 1988. Remaining Shuttle operations activities will be implemented in close coordination with NASA to ensure a safe and smooth transition of the appropriate activities to CSOC.

Eastern Space and Missile Center (ESMC). ESMC, at Patrick AFB, Florida, provides launch, range-safety, and data-acquisition support for developmental and operational test launches of ballistic missiles, such as the Navy's Poseidon and Trident fleet, Army's Pershing I and II missiles, and the Air Force's short-range attack missile (SRAM). ESMC also supports low-inclination-orbit DoD, NASA, and NASA-sponsored space programs. During 1984, ESMC supported 15 major space test operations, including six space shuttle launches.

Western Space and Missile Center (WSMC). WSMC, at Vandenberg AFB, California, provides launch, range-safety and data-acquisition support for development and operational test launches of Minuteman and Peacekeeper missiles and for DoD and NASA space programs requiring polar orbit. The cruise missile and B-1B bomber dominated the aeronautical tests supported during 1984. In 1984, WSMC supported nine major space test operations and three launches of the Peacekeeper missile. Construction of the Space Transportation System's Western Launch Site continued at a fast pace.

White Sands Missile Range (WSMR). WSMR continued to provide support to DoD and NASA aeronautics and space programs. NASA programs were the Space Shuttle, upper atmospheric soundings using rockets and balloons, and a variety of astronomical test programs. The full spectrum of launch, flight, and recovery services were provided including both ground and flight safety, range surveillance, necessary command and control activities, and associated data acquisition and analysis. Space Shuttle activities at WSMR include post qualification tests on the orbital maneuvering system and on forward and aft reaction control systems, evaluation of the Shuttle spacecraft, operation of the Tracking and Data Relay Satellite System to track and relay Shuttle data back to earth, and Shuttle flight and landing support. Past efforts include construction of a second landing strip, construction of facilities for post-landing deservicing, preparation for ferrying, preparation of a public affairs plan to handle the multitude of visitors to WSMR during and after a landing, provision of overall security support, conduct of astronaut recovery exercises and established Shuttle night landing capability.

Kwajalein Missile Range (KMR). Kwajalein Missile Range continued support for DoD and other users as the major test range for defensive missile forces and terminal-area testing of strategic missile forces. Fiscal 84 firing missions at the range included Munuteman operation tests, Peacekeeper developmental tests, and support to the Homing Overlay Experiment. Mission workload and space surveillance support is expected to continue in 1985. KMR is unique in that there is no other comparable U.S. facility to collect signature data on objects outside the earth's atmosphere, record missile reentry phenomena, provide terminal trajectory and impact data, recover reentry vehicles, and transmit nearly immediate data to mission sponsors. The data collected on nearly all KMR missions met requirements of both strategic offensive and defensive developmental communities, for mutual accomplishments of test objectives and continuous interchange of data at a significant saving in costs.

Arnold Engineering Development Center (AEDC). AEDC at Tullahoma, Tennessee, participates in developing and continuing the operational effectiveness of advanced-technology aerospace systems by conducting tests, engineering analyses, and technical evaluations. A national facility with both government and commercial users, AEDC over the past year supported such projects as the Peacekeeper, Space Shuttle, B-1B, F-16, F-100 and F-110 engines, next-generation trainer, and advanced medium-range air-to-air missile. AEDC operates and maintains some 25 aerospace ground-test facilities, which support aerodynamics, propulsion testing, and space simulations.

Air Force Flight Test Center (AFFTC). AFFTC, at Edwards AFB, California, conducts development tests and evaluations of manned and unmanned aircraft systems, aerospace research vehicles, and aerodynamic deceleration devices. Tests range from engineering simulations before flight to flight tests of fully integrated weapons systems. Its large air space, dry lake beds, isolation, and highly instrumented ranges provide a unique support capaility for many users including three major tenants: NASA's Dryden Flight Research Facility, Army's Aviation Engineering Flight Activity, and the Air Force Rocket Propulsion Laboratory. During 1984, the center supported space, tactical, and strategic systems including the Space Shuttle, F-15, F-16, F-16XL, advanced fighter technology integration (AFTI), F-20, X-29, B-52 integrated weapon system, KC-135R, and air and ground-launched cruise missiles.

4950 Test Wing. The 4950th Test Wing, an Air Force Systems Command (AFSC) unit based at Wright-Patterson AFB, Ohio, flight-tests military systems, subsystems, and components. It operates and modifies test and test support aircraft and is the AFSC test organization responsible for Class II aircraft modification policy. One of its primary support aircraft is the advanced range-instrumentation aircraft (ARIA), which serves key telemetry, data processing, and command and control functions during both aeronautical test flight and space missions. A major project is improving ARIA capabilities by converting from the existing C-135 to the C-18 (Boeing 707) aircraft while concurrently updating installed data-acquisition equipment.

Relations With NASA

Aeronautics and Astronautics Coordinating Board

The Aeronautics and Astronautics Coordinating Board (AACB), cochaired by the Under Secretary of Defense for Research and Engineering and the NASA Deputy Administrator, is the major forum for reviewing, discussing and coordinating policies and program issues of mutual interest to DoD and NASA. Most of the interagency coordination process is accomplished by the following AACB panels: Aeronautics Panel, Manned Space Flight and Launch Vehicles Panel, Space Flight Ground Environment Panel, Space Research and Technology Panel, and the Unmanned Spacecraft Panel.

During 1984, the AACB held its 91st meeting to review and discuss various matters relating to aeronautics and astronautics, such as the development of carbon filament wound cases for the Shuttle's solid rocket boosters, the Shuttle-Centaur integration schedule, performance anomalies experienced with the Inertial Upper Stage, proposal for the construction of a test cell for large solid rocket motors, status of the Space Station, and the DoD/NASA National Space Transportation System Master Plan.

Department of Commerce

Agencies of the Department of Commerce involved in the nations's aeronautics and space program during 1984 were the National Oceanic and Atmospheric Administration (NOAA), National Bureau of Standards (NBS), and National Telecommunications and Information Administration (NTIA).

The National Oceanic and Atmospheric Administration (NOAA) conducts research and gathers data about the oceans, atmosphere, space, and sun, and applies this knowledge to products and services beneficial to all Americans. NOAA operates the nation's civil environmental satellite systems. Data from these systems are used by NOAA to assess the effect of natural factors and human activities on global food and fuel supplies and on environmental quality; to observe and forecast weather conditions, provide warnings of severe weather, and assist community-preparedness programs for weather-related disasters; to prepare charts and coastal maps for geodetic research; to aid in the assessment and conservation of marine life; to meet the needs of public and private users, including scientists; and to help researchers to improve the nation's environmental monitoring and warning service.

The National Bureau of Standards is responsible for establishing and maintaining national standards of measurement and provides government, industry, and academia with the measurement services and fundamental physical, chemical, and engineering data to serve national goals. NBS supports space systems, atmospheric and space research, and aeronautical programs.

The National Telecommunicaitons and Information Administration, the principal communications adviser to the President, develops and coordinates executive branch policy in telecommunications and information. NTIA also is responsible for managing the radio spectrum assigned for Federal use and provides technical assistance to other federal agencies.

Space Systems

Satellite Operations

Polar Orbiting Satellites. During 1984, NOAA 6 and NOAA 7, the primary data-gathering weather satellites, orbited the Earth about the poles in sun-synchronous orbits and provided environmental observations of the entire earth four times each day. NOAA 6 crosses the Equator southward at 7:30 a.m. local time, and NOAA 7 in a Northward direction at 2:30 p.m., each carrying four primary instruments: the Advanced Very-High-Resolution Radiometer (AVHRR), the TIROS Operational Vertical Sounder (TOVS), the Argos Data-Collection and Platform-Location System (DCLS), and the Space Environment Monitor (SEM).

NOAA 8, launched in March 1983, was the first in a series of new Advanced TIROS-N (ATN) spacecraft and carries additional instruments for Search and Rescue (SAR). A failure in the clock oscillator, which caused loss of all spacecraft timing signals, made NOAA 8 inoperative on June 12, 1984. This failure interrupted the search and rescue mission until the launch of the next NOAA spacecraft. Reactivated as a replacement for NOAA 8, NOAA 6 was able to support most of the primary mission requirements in 1984.

NOAA F. This satellite became NOAA 9 after its launch on December 12, 1984. It is not a true replacement for NOAA 6 or 8. Both 6 and 8 are "morning satellites" engineered for equatorial crossings at about 7:30 a.m., local times; NOAA 9, like NOAA 7 is an "afternoon satellite," with thermal controlling louvers and sunshades adjusted for 2:00 p.m. equatorial crossings, local times. However, NOAA G, scheduled for launch in 1985, will be a replacement for NOAA 8. Meanwhile, in addition to its regular complement of sensors and data relay functions, NOAA 9 carries a three-instrument array of NASA sensors for the measurement of earth radiation budget factors, including backscatter to space of solar ultraviolet light, and Earth-radiated thermal (infrared) radiation. These instruments will fly on NOAA 9 and G spacecraft in concert with the NASA Earth Radiation Budget satellite.

NOAA H, I, and J. These polar orbiting satellites are under contract for delivery in the last years of this decade. Beginning with NOAA H (October 1986), all NOAA-series afternoon satellites will be configured for earlier afternoon equatorial crossings at approximately 1:00 p.m. local times. This orbit change will permit earlier remote sensing of the Eastern Pacific region adjacent to the U.S. west coast to feed atmospheric temperature profiles and surface temperatures to the

National Weather Service in time for its numerical prediction computations.

Geostationary Satellites. The year 1984 began with two of NOAA's geostationary operational environmental satellites (GOES). The primary imaging spacecraft of GOES systems were GOES 5 at 75° West and GOES 6 at 135° West. On July 30, the imager on GOES 5 failed, requiring a repositioning of GOES 6, over the central U.S. to provide, as best it could from that location, visible and infrared imagery coverage of the Atlantic and Pacific coasts using its Visible Infrared Spin Scan Radiometer (VISSR) Atmospheric Sounder (VAS). GOES 6 was relocated from 135° West to 98° West for the hurricane season and then to 108° West for maximum coverage of winter weather coming off the Pacific Ocean and Gulf of Alaska. To compensate for moving GOES 6 away from 135° West, GOES 1, a standby spacecraft, was reactivated on August 27, 1984 at 130° West to provide visible imagery to extreme western users. Goes 1 subsequently failed on September 7, 1984, leaving GOES 6 as the lone imaging spacecraft. Failure of the GOES 5 imager did not impact the operation of its Data Collection System (DCS), its Space Environment Monitor (SEM), or its Weather Facsimile (WEFAX) broadcast capability.

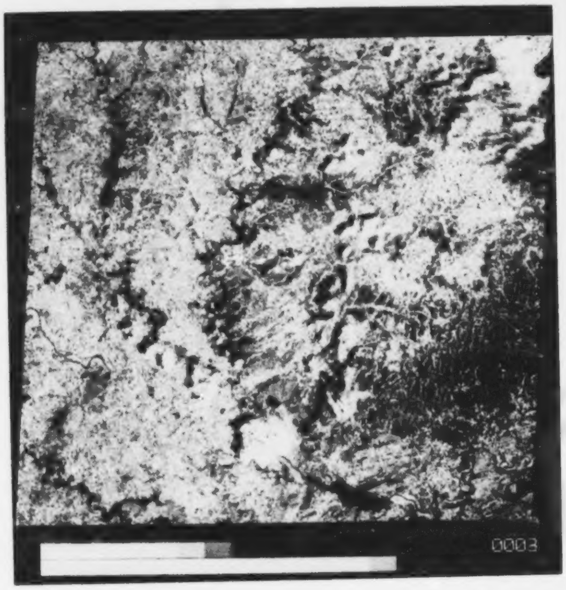
The next launches of GOES spacecraft are scheduled for the winter of 1985/86 and spring/summer 1986.

"GOES-Next." Acting for NOAA, NASA will purchase "GOES-Next" satellites for flight during the 1990's. The Request for Proposals was released June 29, 1984, proposals were received August 27, and expected contract award is Spring 1985. Improvements include concurrent imaging and atmospheric sounding (not available with the present GOES), additional information for atmospheric movement of water vapor, and relocation of picture elements to permit better calculation of winds from images showing cloud motions.

Land Satellites. The Landsat Earth observation system in 1984 consisted of two Earth-orbiting satellites (Landsat 4 and 5) and a control and data processing facility located at Goddard Space Flight Center (GSFC). This system originally was developed by the National Aeronautics and Space Administration (NASA), and the first satellite (Landsat 4) was launched successfully by that organization on July 16, 1982. Authorized to manage the system by Presidential Directive PD/NSC-54, NOAA assumed operational responsibility for Landsat 4 on January 31, 1983.

During its first seven months in orbit, Landsat 4 developed a series of technical problems that severely curtailed its capability to achieve mission objectives. As a result, the decision was made to launch Landsat 5. This was accomplished successfully on March 1, 1984.

Both Landsat 4 and 5 carry indentical Earth-observation sensor packages. The multi-spectral scanner (MSS) measures reflected solar radiation over four bands in the visible and near-infrared wavelength regions at 80-meter resolution, and its experimental thematic mapper (TM) measures over 6 bands in the visible infrared wavelengths at 30-meter resolutions and 1 band in the thermal infrared. While Landsat 4 is capable of supporting only the MSS portion of its mission, Landsat 5 is supporting full mission requirements for both MSS and TM.



Landsat-5 thematic mapper image of Oklahoma/Missouri/Arkansas tri-state area, shows Tulsa, Oklahoma and the northeastern corner of Oklahoma, as well as the very southwestern corner of Missouri and the northwestern corner of Arkansas.

MSS data are available for most of the contiguous United States, Alaska, most of Central and South America, northern Europe and northwest Russia, Japan, and near neighboring areas of Asia and Australia. Limited TM data are available for the contiguous United States and the areas of coverage of NASA's Tracking and Data Relay Satellite System (TDRSS). Data are distributed through the Department of the Interior's Earth Resources Observation System (EROS) Data Center in Sioux Falls, South Dakota, and through foreign facilities in countries with Landsat ground stations (Argentina, Australia, Brazil, Canada, India, Italy, Japan, South Africa, Sweden, and Thailand).

During 1984, through the agreement with the Department of Interior (DOI), NOAA added 33,000 MSS scenes and 4,000 TM scenes to its archives. Some

3,000 digital products and 35,000 photographic products were distributed to Landsat customers as well. These are sold at prices designed to recover a higher percentage of the cost of operating and managing the Landsat system.

Commercialization

On February 28, 1983, the President directed the Secretary of Commerce to investigate the possible transfer of weather and land satellites to the private sector. In April 1983, the Secretary of Commerce established two interagency groups to undertake this determination:

- The Interagency Board on Civil Operational Earth-Observing Satellite Systems (IB-COESS), and
- The Source Evaluation Board for Civil Space Remote Sensing (SEB).

These two groups had complementary functions. The IB-COESS, composed of assistant secretary-level policy officials and chaired by the Deputy Administrator of NOAA, provided policy review and guidance for the Department's activities. The SEB, composed of representatives from IB-COESS member agencies and chaired by a representative from the Department of Commerce, was to accomplish the following:

- Define the policy and technical issues for resolution by the IB-COESS or the Secretary of Commerce,
- Develop the Request for Proposals (RFP) for the satellite systems, and
- Evaluate responses to the RFP for the Secretary of Commerce.

The Congress passed several non-binding resolutions in mid-1983 indicating little support for the possible "sale" of the weather satellites. Finally, in late October 1983, the Congress passed the Department of Commerce's appropriation bill which included an amendment prohibiting any further consideration of weather satellites for "commercialization."

However, before the Congress stopped the process for the weather satellites, the SEB had completed a draft RFP that had been approved by the IB-COESS and released for public comment. The draft RFP was issued on October 21, 1983, and asserted that these civil systems support traditional government roles to provide for the health, safety, and economic well being of its citizens.

P.L. 98-365, passed in June 1984, also reaffirmed the priority of these traditional roles in the context of newly evolving Government-commercial relationships.

On September 19, 1984, the Department of Commerce Civil Space Remote Sensing (CSRS) Commercialization Group, (formerly Source Evaluation Board), presented its Report to Congress per requirements of PL 98-365. Titles II and III require a report to Congress prior to implementation of Secretary Baldrige's decision to contract for commercialization of the Landsat system. The report documents the history of the administration's efforts to move civil satellite remote sensing into the private sector and updates events since the selection of Eastman Kodak and EOSAT for final negotiations.

Initial meetings were held with each firm on June 29, 1984. At these meetings, both firms were informed that their technical approaches were acceptable, but their financial proposals were unacceptable as submitted. Each offerer was given until July 9, 1984, to revise its proposal to reduce the cost and/or financial risk to the U.S. government. The revised proposals and the Government's refined financial analyses confirmed that, in the worst case, Government liability over the life of the program would have an adverse impact on efforts to reduce the Federal Budget. After consultation within the Administration, the President concurred in a decision by Secretary Baldrige and Office of Management and Budget Director Stockman that government financial support for the establishment of the commercial system should be limited to (1) the runout of Government cost for operating Landsats 4 and 5; plus (2) a maximum of $250 million of new budget authority for the development and procurement of the commercial follow-on system of not less than 10 satellites.

Both offerers were notified of this decision on July 20, 1984, and were requested to revise their proposals accordingly. EOSAT reduced requested Federal financial support in a proposal revision that also included certain technical changes, but Eastman Kodak declined to revise its proposal to meet the Government's conditions.

Satellite Data Services

DCS. The GOES Data Collection System (DCS) relays in real time environmental data from remotely located Data Collection Platforms (DCP's). At the end of 1984, there were 4,970 DCP's an increase of 394 during the year. Data are distributed to 76 national and 27 international users, and there are 27 passive direct readout stations (21 domestic and 6 non-U.S.). GOES DCS reliability has been at the 99% level for the year. The Random Reporting Operating Mode was tested operationally for 24 months and in 1984 was declared operational for the GOES DCS. The 1984 NOAA ground system is expected to reach saturation during calendar year 1985 when more than 5000 DCP's will be in the system. A revised *User Interface Manual* and a *Users Guide to Random Reporting* were published in 1984. Also completed in 1984 was the channel realignment program, whereby all even-numbered channels are on the west spacecraft and oddnumbered channels on the east. New 80 M bite disks were installed at the DCS installation in Camp Springs; and the 22 M bite disks, formerly at Camp Springs, were moved to the Wallops Station to replace the 10 M bite disks. These disk changes have increased ground system message storage by 100%.

WEFAX. The Weather Facsimile (WEFAX) service in 1984 continued to use three of the GOES spacecraft to broadcast satellite imagery, meteorological analyses and prognoses, and operational and ephemeris messages. The number of known WEFAX users total 200 (96 domestic and 104 non-U.S.). Broadcast schedules were expanded in 1984, and 567 products are broadcast each day on a 24-hour basis. A new 7-meter antenna to support WEFAX broadcasts was installed recently at Wallops Station.

Ocean Products Center. An Ocean Products Center staffed by personnel from the National Ocean Service (NOS), the National Weather Service (NWS), and the National Environmental Satellite, Data, and Information Service (NESDIS) was established on October 1, 1984. The Center is colocated with the National Meteorological Center at the World Weather Building in Camp Springs, Maryland. The mission of the center is to develop, prepare, and disseminate various marine meteorological and oceangraphic guidance products in support of NOAA field offices. Products currently produced or under development fall into the following five basic categories: marine weather; waves and wave dynamics; ocean thermal structure and dynamics; ice and ice dynamics; and estuarine circulation and coastal processes.

GOES VISSR Atmospheric Sounder (VAS) Assessment. In support of the NOAA Operational VAS Assessment (NOVA) program, a prototype VAS processing work station was installed in the NWS National Meteorological Center (NMC). The work station is connected to a prototype VAS Data Utilization Center which is under development at the University of Wisconsin by the NESDIS Development Laboratory and the Space Science and Engineering Center. The VAS work station at NMC is being evaluated by scientists from NMC's Heavy Precipitation Branch and NESDIS's Interactive Processing Branch and Satellite Applications Laboratory. Initially, new GOES-VAS products being evaluated include temperature and moisture profiles, cloud drift winds, several instability indices, and new image products. During the winter of 1983-84, GOES-VAS data over the eastern Pacific region were added into NMC's synoptic forecast models to determine their impact.

Geophysical Data Bases. The National Geophysical Data Center (NGDC) archives, publishes, and analyzes various geophysical data bases including space environment and cryospheric data recorded on NOAA satellites and some NASA and DOD satellites. Satellite data archives during 1984 included the new GOES Space Environment Monitor data, the new DMSP electron and ion data, the DMSP night-time auroral imagery, and the DMSP images of clouds, snow and ice illuminated by sunlight or moonlight. Most of the users of these data bases are in the scientific research community. Data from GOES, IMP, and Pioneer spacecraft are published monthly in *Solar-Geophysical Data* reports, largely for use by scientists and operators of near-Earth communication systems. Analysis of ground-based magnetic variations records was undertaken to support ISEE-3 and DE satellite programs of NASA. Research was initiated to build an improved model of the near-Earth particle and field environment in the polar region upper atmosphere in support of DOD requirements.

Cryospheric Data Management System. The National Snow and Ice Data Center started a Cryospheric Data Management System to process, archive, and distribute passive microwave data recorded on DMSP satellites. These data offer continuous measurement of the distribution of sea ice and snow cover and the percentage of new sea ice versus multiyear ice cover for use by the climate research and energy development communities.

Satellite Anomaly Data Base. Within the Solar-Terrestrial Physics Division of NGDC, a data base was started to document the relationship between solar activity, space environment changes, and consequent problems with operation of geostationary and polar orbiting satellites. The objective is to provide information to improve routine satellite operations, assist users of communications satellites in interpreting causes of problems, and to provide satellite and instrument designers with a basis for future improvements. This systematic data and information collection also should support research into the different enviromental effects of solar emissions, galactic cosmic rays, and any other sources of energetic charged particles in near-Earth space.

Satellite Data Uses

Space Shuttle Support. The use of NOAA polar satellite information, imagery, and digital data was established and is now integrated into segments of the NOAA Space Shuttle Program at the Johnson Space Center, Houston, Texas. NOAA satellite imagery is used in pre-flight crew briefings and during a mission to plan orbit by orbit photographic activities. The digital data are used in post mission evaluations. Shuttle photography is compared to satellite data to study environmental trends and survey meteorologic, hydrologic, and oceanographic phenomena.

Vegetation Index Service. In May 1984, NESDIS and NWS initiated a new experimental service—the production and distribution of a Vegetation Index image. The goals of the 4 month experiment were to distribute the Vegetation Index image to NWS field offices twice weekly and to determine its usefulness to agricultural interests. The Vegetation Index image is distributed by the NWS-Washington Satellite Field Services Station through its GOES-Tap network. The image is in a mapped mercator format with imbedded annotation. Created by a hydrologist using an interactive computer system, the imbedded annotation is designed to direct first time users of this new product to specific areas of interest within the image. Continuation of the product and its transition from experimental to operational mode will be dependent upon the user evaluations of product usefulness and demand.

Fire Detection. The 3.8 micrometer thermal infrared channel on the NOAA polar-orbiting satellites continued to be used to detect and monitor fire activity throughout the world. This channel is very sensitive to high temperature sources such as fires and, in conjunction with the other thermal channels on the satellites, can be used to calculate fire area and temperature. Over 300 fires related to seasonal slash and burn agricultural activities were detected on just one day in Mexico. In Siberia, 60 detected lightning-induced forest fires created a 1.5×10^6 km^2 area of smoke lasting over 2 weeks. Of particular concern to those interested in deforestation was the detection of a huge area (approximately 2° latitude × 2° longitude) of clear cutting and associated fire activity in western Brazil. The National Climate Program Office also expressed interest in using the NOAA satellite capabilities for fire and smoke detection as a method for providing data to check the "nuclear winter" studies.

Volcano Monitoring. Seven volcanic eruptions were detected and monitored using NOAA polar-orbiting satellite data. The volcanoes are Pavlof (Alaska), Mauna Loa (Hawaii), Pagan (Mariana Islands), Merapi (Java), Mt. Etna (Italy), Kliuchevskoi (U.S.S.R.), and Soputan (Indonesia). The satellite information was sent to the Smithsonian Scientific Event Alert Network for dissemination to the scientific community, other Federal and state agencies, and foreign governments.

The Federal Aviation Administration (FAA) and NOAA continued to work to implement an operational plan for detection and monitoring of volcanic hazards to aviation using NOAA satellite data. NOAA has responded to a draft statement of the requirements from the FAA.

Bennett Island, U.S.S.R. "Mystery Plumes." The "mystery plumes" originating near Bennett Island (76.7°N, 149.3°E) and first detected in 1983 using NOAA polar-orbiting satellite data, continued to be detected. Fifteen cases were observed in 1984, including a plume event detected by the Landsat-5 satellite. Several of the plume events were 50-100 km long. It is believed now that the plume events are not volcanic in origin but are the result of methane gas venting from the continental shelf below the island. The world's largest gas fields are in northern Siberia, and what may have been discovered on the NOAA satellite imagery is evidence of the world's largest gas seep. If so, it could have commercial value for the Soviet Union.

Rainfall. NOAA has developed and implemented new software for the Interactive Flash Flood Analyzer (IFFA) that has improved the timeliness and accuracy of satellite-derived rainfall estimates. In the first full year of operation, the IFFA system was used in more than 5,000 hours of satellite estimates. Messages relaying these estimates instantly to flash flood forecasters provided extremely critical data for decision making about timing and location of flash flood warnings. Recent studies have verified the reliability of these estimates as one of the primary sources of guidance for the issuance of flash flood watches and warnings. During Hurricane Diana, NOAA meteorologists calculated maximum rainfall estimates of 20 inches over eastern North Carolina in a 2-day period. Actual reports were as high as 18 inches. During the winter of 1984, the IFFA operation was expanded to include estimates of heavy rain and heavy snow in winter storms. These estimates also provided short-range outlooks that supplied forecasters with on-going trends for the location and intensity of heavy precipitation.

Severe Storm Support. In preparation for operational implementation of temperature and moisture data obtained from the geostationary satellites, NESDIS, in cooperation with the University of Wisconsin, provided support to the National Weather Service in three phases. First, data were provided over the eastern Pacific Ocean for the numerical forecast model at the National Meteorological Center during the winter. Second, data were provided to the National Severe Storms Forecast Center during the spring and summer. Third, data were prepared for the National Hurricane Center during the fall. However, the failure of GOES-5 sharply curtailed this last activty. The value of the geostationary soundings and of new applications with water vapor imagery is gaining increased acceptance as methods are developed to make these data reliable and informative. Small computer interactive techniques to exploit these data are being incorporated into systems to upgrade the national centers.

Food Shortage Alerts. NOAA continued to use and test a crop monitoring system that relies on data obtained from radiation measurements by the NOAA-7 satellite. This supplements the existing system, which uses surface rainfall reports, plus cloud cover information from the NOAA-7, to monitor crop health. The possibility of drought in developing countries and regions in the tropics is examined. Assessments concerning drought-related food shortages are sent weekly to Office of Foreign Disaster Assistance of the Agency for International Development (AID) officials in the affected countries.

The new supplement provides two more tools for assessments: a time-series of weekly crop-health indices for a specific crop region and a color-coded image for a large part of any continent for a specific week. The technology to process the satellite data is being transferred to those countries with the required computer and satellite-signal reception equipment enabling them to make their own crop-signal reception assessments. A meeting with nine Southeast Asia nations in Thailand during May 1984 started the technical transfer process.

Global Mapped Vegetation Index. NOAA funding from AgRISTARS (Agriculture and Resource Inventory Surveys through Aerospace Remote-Sensing)—a joint program of NASA, NOAA, and Department of Argiculture—is evaluating the use of satellite data in providing crop estimates. The NOAA global mapped vegetation index depicts the extent and "greenness" of vegetation worldwide. Global AVHRR data are collected daily, and a vegetation index is computed and mapped to a polar stereographic (PSG) projection. A weekly composite vegetation index is produced from the daily data.

Production of PSG mapped vegetation indices are provided in tape and image form to AgRISTARS for evaluation, and copies are available to any interested party. Production began in April 1982 and will continue through September 1986.

Fisheries. At the Southeast Fisheries Center, SEASAT-A scatterometer data in 1984 have been used to compute wind-induced surface currents and to delineate areas of upwelling and downwelling, information valuable for determining the direction of transport of fish eggs and larvae. Shrimp, for example, spawn offshore and depend on currents to transport their eggs and larvae into estuarine nursery grounds where the shrimp mature. If surface currents are moving offshore during peak spawning periods, the number of shrimp entering the estuaries will be reduced and the fishery impacted. The short life of SEASAT-A prevented verification of this technique, but comparisons of derived current patterns from SEASAT-A and patterns computed from conventional wind data show that SEASAT-A data provide a more detailed quantitative picture of ocean currents. Refinement of this technique will provide a valuable tool for forecasting recruitment and yields of shrimp and other species dependent on this transport mechanism.

The Southeast Center also continues to use data from the Coastal Zone Color Scanner (CZCS) to detect and map areas of hypoxia in the northern Gulf of Mexico. Hypoxia, a condition where oxygen concentrations in bottom waters is near zero, is not well understood and appears to occur frequently in the northern Gulf. Location of areas of hypoxia is important to fisheries because these waters with low oxygen content will support few, if any, shrimp or finfish and may block normal migration patterns of these animals.

Additionally, the Southeast Center has used successfully satellite data transmission links to transmit fisheries and environmental survey data from survey ships to data users. Daily transmissions of survey data, made from the ships to shore-based computers through the ATS-3 satellite and through portable ARGOS transmitters, were summarized on charts and distributed weekly to fishermen, fishing associations, State fishery management organizations, and others for various applications.

The ATS system also was used by fishery scientists participating in the AMERIEZ (Antarctic Marine Ecosystem Research at the Ice-Edge Zone) program to study physical and biological processes active during the retreat of the ice edge. The scientists at the Northeast Fisheries Center received near realtime ice maps from NASA/Goddard derived from NIMBUS-7 microwave data. The maps were sent to research vessels by means of the ATS system. In return the scientists at sea transmitted wind data back to NASA/Goddard for use in analyzing changes in ice cover.

At the Southwest Fisheries Center, CZCS, and AVHRR data are used to produce charts showing the location of ocean color boundaries or fronts. These charts are used widely by tuna fishermen to locate favorable areas for fishing. Studies at the Center have shown that the tuna tend to concentrate in the warm, bluish oceanic water along the fronts. Very few or no tuna are found in the cooler, greenish colored coastal waters. In 1984, satellite information was particularly useful in locating fish. Because of the abnormal warming of ocean waters resulting from the El Nino phenomenon, many fish have been displaced northward and are not found in their usual areas. The satellite data have provided the information required to locate the areas where appropriate temperature conditions exist for fish that are hundreds of miles from their traditional location.

The CZCS imagery also is used by the Southwest Center to describe ocean processes related to spawning of northern anchovy. Imagery was collected coincident with fine grid oceanographic ship observations. Preliminary results indicate that anchovy avoid areas of low chlorophyll concentrations, presumably because of insufficient food availability. Additionally, CZCS data are being used to investigate distribution and abundance of juvenile salmon off the Oregon-Washington coast.

Scientists at the Northeast Fisheries Center have used satellite infra-red imagery and digital data in a study of the distribution of *Illex* squid in outer continental shelf waters off the northeastern United States. Analysis of 1,100 commercial catch records and coincident satellite data for fall seasons of 1980, 1981, and 1982 showed that 80-100 percent of the high catch rates were found within 10 miles of the shelf-slope front, even though only 50-60 percent of the fishing effort was directed there.

The Northeast Fisheries Center has joined with a community of Federal, state, and private users of remote sensing data to form the Northeast Remote Sensing System (NEARSS) Association. The Association focuses on solution to the problems of member institutions in acquiring and using, efficiently and economically, remote sensing data collection and data analysis techniques. Through contributions from these institutions, a regional net for distribution of analog images transmitted by NOAA over the GOES-tap has been established. The long-term goal is to obtain near-real-time access to full resolution digital data from NOAA's polar orbiting satellites.

The Coastal Habitat Assessment Research and Mensuration (CHARM) program at the Northeast Center, designed to respond to the national goal of zero net loss of wetlands productivity, is particularly concerned with the effect of wetland loss or modification because the wetlands provide and support habitats suitable as spawning, nursery, and feeding area for 96 percent of the commercial fisheries and 50 percent of the recreational catch. The approach is to use LANDSAT data to provide a uniform format to classify and monitor wetlands and to integrate the results to determine the effects on fisheries.

Satellite infra-red imagery also has been used by the Northeast Center to delineate the areas affected by the plumes from the Chesapeake, Delaware, and Raritan Bays. The plumes contain biostimulants, contaminants, and other materials which can have an effect on benthic and pelagic resources.

Marine Assessment Application of Satellite Data. The Chesapeake Bay is the site of an assessment to evaluate meteorological and oceanographic processes in conjunction with their possible impact on fishery recruitment. The physical processes (i.e., winds, currents, tides) which control the exchange of waters between the Chesapeake Bay and adjacent continental shelf also influence the passive transport of fish eggs and larvae. Recruitment of several fish species in the Bay, particularly menhaden, depends in part on the quality of larvae transported from the shelf into the Bay. Satellite data are being used to observe the behavior of large water masses and the generation and interaction of fronts and eddies as water enters and exits the Bay. Visible and thermal infrared data from the Nimbus-7 Coastal Zone Color Scanner (CZCS), the NOAA-N series of Advanced Very High Resolution Radiometers (AVHRR), and Landsat are all being analyzed for this assessment. Since pelagic fish eggs and larvae are transported in the surface layer, satellite observations of surface sediment and temperature plumes by AVHRR and Landsat can be utilized as markers for fish transport. The CZCS data are used to identify water masses by their chlorophyll concentration in addition to temperature. Satellite data from 1977 to 1983 are analyzed in conjunction with current, tide, and wind data to track surface plume movements. The results of this analysis then will be correlated with fishery data and the surface transport values generated by the Limited Fish Mesh (LFM) wind mode. This study will yield further insights into climate-fishery interactions, improve our ability to assess fishery recruitment in the Cheaspeake Bay, and provide for better utilization of fishery resources.

Other Uses of Satellites

International Activities

CGMS. The Coordination of Geostationary Meteorological Satellites (CGMS) group met in Geneva, Switzerland in April 1984. Representatives from the European Space Agency, Japan, U.S.S.R. and the U.S. participated. Meeting highlights included determining an acceptable method for assigning data collection system resources to support the new Aircraft to Satellite Data Relay, refining plans to make the different meteorological satellite systems compatible, and reviewing satellite born sensor calibration techniques and products made from these instruments with a view to making them interchangeable.

ARGOS. The ARGOS Data Collection and Location System (DCLS) provided by France operates on the present NOAA polar-orbiting spacecraft. Of the nearly 500 active platforms operated by organizations from 17 countries, 70% require location calculations; and 10% disseminate data via the Global Telecommunications System. Including the U.S., 14 countries were members of a joint tariff agreement for use of the ARGOS DCLS in 1984.

Training for Foreigners. The National Environmental Satellite, Data, and Information Service (NESDIS) conducts in-house training and participates in training seminars and workshops to improve the quality and exchange of satellite data and to contribute to cooperative research activities. During 1984, NESDIS conducted training for ten foreign nationals from five countries in such fields as meteorological satellite data processing, agrometeorology, and seismology data management. Each of approximately sixteen trainees from nine countries received 6 weeks of training at NESDIS under the NOAA/AID Project called Global Climatic Impact Assessment Technology for Drought/Disaster Early Warning and Technical Assistance.

International Radio Regulations. The National Telecommunications and Information Administration (NTIA) is responsible for developing the Federal Government's proposals to the International Telecommunication Union (ITU), the United Nations agency that establishes and administers international regulations concerning the use of the radio spectrum, including its use by spacecraft. The Radio Regulations are modified when the need arises by the convening of an Administrative Radio Conference. The ITU held a Regional Conference in 1983 concerning the development of a plan for the use of broadcast satellite frequencies affecting the Western Hemisphere. In 1984, several meetings under the ITU took place concerning the development of technical recommendations for space communications by the International Radio Consultative Committee (CCIR). NTIA participated in all these activities.

World Radio Conference on Space Communications. NTIA continued to lead government agencies in preparations for the two-part 1985 and 1988 World Administrative Radio Conference for space services (Space WARC). NTIA played a key role in the U.S. delegation to the technical preparatory meeting of the CCIR, which was convened in June 1984. This meeting provided a balanced technical input on various planning techniques to be considered sequentially by the Space WARC. NTIA has been coordinating the development of proposed positions and strategies on behalf of Federal agencies for use in subsequent Space WARC negotiations. Also, NTIA has been developing a computer-based model, the Geostationary Satellite Orbit Analysis Program (GSOAP), for analyzing orbit and spectrum use.

Advanced Communications Technology Satellite Experimentation. In 1984, NTIA also began preliminary planning for communication experimentation to be accomplished via the NASA Advanced Communications Technology Satellite (ACTS). These plans provide the basis for advanced satellite communication technology assessments including systems performance measurements, antenna directivity and pointing accuracy, and other relevant factors. In this connection, NTIA has reached agreement with NASA for loan of a portable earth terminal for initial experimentation.

COMSAT Corporation. In cooperation with the Department of State and the Federal Communications Commission, NTIA participates in overseeing the Communications Satellite Corporation's activities in the International Telecommunications Satellite Organization (INTELSAT) and the International Maritime Satellite Organization (INMARSAT). INTELSAT's annual circuit growth rate was decreasing in 1983 and through the first half of 1984. Its revenues for full time services grew at a rate of approximately 13% in 1983. Its capital ceiling remains at $2.3 billion. No additional orders were placed above the initial orders of five Intelsat VI series communications satellites. These satellites have about 25 percent greater capacity than the Intelsat V series. COMSAT retains options to order up to seven more Intelsat VI satellites.

Network Protocols. The National Bureau of Standards is working with COMSAT in a joint research project to evaluate the performance of computer network protocols over satellite networks. The network protocols, now being developed by international and national voluntary standards groups with NBS assistance, are designed to work over different communications technologies. The objective of the work of NBS with COMSAT is to develop needed test methods for measuring the reliability of data transmitted through global satellite networks. Results of the research will advance development of network products that implement the Open Systems Interconnection (OSI) concept and that operate in a multi-vendor and mixed communications network environment.

Geodesy

Global Positioning. The application of Global Positioning System (GPS) technology to geodetic position determinations has been shown to be more efficient, more economical, and more accurate than classical geodetic survey methods. But the full potential of this new system cannot be realized until experience has been gained in its use; the full satellite coverage planned has been effected; and the data processing, handling, and analysis procedures have been worked out. During 1984, the National Geodetic Survey (NGS) worked toward the achievement of these goals by carrying out over 20 GPS survey projects at various locations throughout the country. Data from GPS surveys will be incorporated into the National Geodetic Reference System. In April 1985, at Rockville, Maryland, Charting and Geodetic Services (C&GS) will co-sponsor with the Defense Mapping Agency, the International Association of Geodesy, and the International Union of Geodesy and Geophysics, the "First International Symposium on Precise Positioning with the Global Positioning System." Some of the topics to be discussed are: physical modeling, algorithms, processing, orbit determination, instrumentation, applications, precise positioning results, and comparisons with other precise positioning systems.

POLARIS Network. In January 1984, the Richmond POLARIS (Polar Motion Analysis by Radio Interferometric Surveying) Observatory, near Miami, Florida, became operational, thus completing the three-station Very Long Baseline Interferometry (VLBI) network in the United States that provides high accuracy determinations of Earth rotation and polar motion. The other stations in the network are located near Fort Davis, Texas (the George R. Agassiz Station), and near Boston (the Westford Observatory). Radio telescopes at two or more of the observing stations simultaneously observe signals emitted by faint, distant radio sources (typically quasars), believed to be billions of light-years from Earth. Also in January 1984, the Wettzell Observatory in the Federal Republic of Germany became operational. The combined POLARIS-Wettzell network now forms the primary International Radio Interferometric Surveying (IRIS) system. The Onsala Space Observatory in Sweden participated with IRIS by joining in one observing session per month. As the operational center for IRIS, NGS develops and distributes schedules for the observations, reduces the observational data, and distributes the polar motion and Earth rotation data. VLBI measurements have shown that this technique can be used to study large-scale interactions between the Earth's mantle, atmosphere, and oceans, thereby contributing to an understanding of the processes underlying geophysical and climatological phenomena.

Satellite Altimetry. The use of space technology also has been applied to the determination of other geodetic parameters that heretofore were thought to be unattainable. The most important example is the measurement of sea surface by satellite altimetry. The form of the ocean surface is determined predominantly by the Earth's gravity field, allowing accurate geoid determinations of nearly all the oceans, an achievement impossible to carry out using classical shipboard gravity measurements. The remainder is due to time varying ocean dynamic processes. Although this is a relatively small contribution to sea height, it still is large enough to be detected and measured by satellite altimetry providing both regional and global views of ocean circulation. Satellite altimetry has been applied to the study of the undulations of the geoid which correlate with sea floor topography—the gravitational attraction of massive sea floor features such as sea mounts, trenches, ridges, oceanic rises, and fracture zones which produce bumps on the sea surface that can be mapped by satellite altimetry. In 1984, NGS produced 32 overlays of sea surface topography profiles for 16 maps of the General Bathymetric Chart of the Oceans series. The overlays display sea surface slopes along the satellite tracks. In poorly charted areas, the satellite altimeter has revealed many undetected features of the sea floor. Nearly 100 previously undiscovered sea mounts were found in the South Pacific.

Surface currents can be measured as sea surface slopes relative to the geoidal surface. In 1984, progress was made toward the ulimate goal of determining long-term general circulation of the oceans with the preparation of a global map of ocean circulation altimeter data together with a model of the gravity field. Last year NGS developed a new technique based on satellite altimetry data to monitor the sea level changes caused by the occurrence of El Nino with an accuracy of a few centimeters. When used with the absolute global reference frame provided by the VLBI/GPS network, it should be possible to monitor large-scale sea level variability in the tropical oceans with data provided by the Navy's GEOSAT altimeter satellite scheduled for launch early in 1985.

Geodynamical Measurement Methods. Scientists at NBS are helping NASA improve the accuracy of its geodetic experiments. One such experiment involves the use of the passive Laser Geodynamics Satellite (LAGEOS) to determine worldwide crustal movements. By measuring the time taken for a laser pulse from a ranging station to reach the satellite and return, position on the Earth's surface is determined to an accuracy of 3 cm. Measurements from two stations at the same site established instrumental errors. A program to colocate a mobile laser ranging station with a fixed station for brief periods to provide additional information on the quality of data was proposed to the NASA Crustal Dynamics Project.

A less accurate but faster and less expensive way of measuring crustal movements involves the use of microwave signals from the Global Positioning Satellite (GPS). LAGEOS measurements take about 1 month per site, but GPS data can be obtained in 2 or 3 hours per site. The University of Colorado and Columbia University have formed a University NAVSTAR Consortium with Caltech, Harvard, MIT, Princeton, and the University of Texas, to make portable GPS terminals available in academic research programs. NBS scientists are helping the Consortium evaluate the accuracy of the GPS data to be obtained in studies of crustal movements in seismic zones.

The accuracy of any microwave distance measurement is limited mainly by the uncertainty in the correction for water vapor in the atmosphere. To determine the microwave distance correction, NBS scientists are constructing an instrument to measure the integrated water vapor content between a transmitter on the ground and a receiving package in an aircraft. Since optical distance measurements are much less sensitive to water vapor, the difference between the measured optical and microwave distances can determine the correction. NASA and the NAVSTAR Consortium are expected to use the NBS instrument to test the accuracy of water vapor radiometers and radiosonde data.

Aeronautical Charting

In 1984, the National Ocean Service (NOS), which produces aeronautical charts and related products for navigation under control of the U.S. national airspace system, continued its support of the Federal Aviation Administration's National Airspace System Plan (NASP). The NASP is intended to enhance the efficiency and effectiveness of the airspace system by improving services to the public. To support this effort, NOS developed new aeronautical prototype products during 1984.

A prototype visual chart was designed and distributed to the public for evaluation in early 1984. The results of this evaluation may require the entire visual chart series to be redesigned. Prototype instrument charts also were developed and evaluated during 1984.

NOS continued its efforts to develop products to satisfy demands generated by advancing technology in aviation. These products may include charts and navigational data in digital format. Alternative methods of presentation, such as charts stored on video disks for playback on cockpit-mounted video displays, also are being investigated.

Orbital Research

Low-Gravity Alloy Processing. NBS developed a theoretical model that can predict instabilities during the solidification of alloys that arise from gravity driven flows in the liquid state. Experiments which demonstrate these flows and the resultant instabilities were conducted at NBS. This work will help identify the kind of experiments aboard the Space Shuttle and the Space Station that will be of scientific value and benefit. NBS also measured fundamental physical parameters, such as surface tension, necessary for containerless processing techniques to be employed in space processing.

First Space-Made Product In July 1984, NASA presented the National Bureau of Standards (NBS) with billions of tiny, uniformly-shaped polystyrene spheres, 10 micrometers (1/2500 of an inch) in diameter, which were produced on space shuttle flights by means of a chemical process developed for NASA by Lehigh University. Once their size and uniformity have been certified by NBS, these tiny spheres will become the first space-made commercial product; a micro-length reference standard. The near perfect spheres are produced in the gravity free environment of space.

On Earth spheres are not uniform and tend to be egg-shaped due to the force of gravity. When certified, the spheres made in space will be an important calibration tool for manufacturers and users of instruments that measure small particles. Accurate measurements of small particles are especially important in equipment to monitor air pollution particulates, in medical instruments to count blood cells or to measure capillary size, and in processing equipment for finely ground products such as paint pigments, inks, ceramic powders, explosives, and chemicals.

Interfacial Wetting. NBS is conducting studies on fluid-fluid and fluid-solid interfaces as prototype experiments for low-gravity research in an orbiting laboratory. An unique optical system for studying how a liquid wets other liquid surfaces and solid surfaces was designed and tested. This pioneering work has stimulated the development of novel techniques for making new material such as those whose composition varies in a well-defined, reproducible manner. The thickness of wetting layers and their persistence with variations in temperature and other key parameters, including gravity, are being studied. Experiments show that current theories are inadequate for explaining the data and that wetting persists over surprisingly large temperature ranges.

High Temperature Liquids. NBS is exploring the feasibility of using low-gravity space environments to measure very high-temperature thermo-physical properties of solids and liquids. Such accurate measurements have heretofore been difficult or impossible on Earth because of the high-temperature containment. An unique thermophysical measurement system developed at NBS, which is capable of making very rapid measurements, provides the key technology for these studies. There is interest in high-melting point refractory metals and alloys such as are used in the construction of nuclear reactors, weapon systems, and spacecraft. Initial measurements conducted aboard a NASA KC135 aircraft verify the ability of the NBS system to sustain a well-defined geometry of liquid for a period of time that is sufficient to complete the required thermophysical measurements.

Space Support Activities

Materials Research

Ablative Coatings. Carbonaceous materials are commonly proposed as protective coatings for shielding spacecraft against laser attack. Upon impact by high energy laser irradiation, these materials dissipate the input energy by converting it into chemical energy in the form of carbon vapor. Understanding of this conversion requires chemical information concerning properties of the intermediate graphite-like layers. Such information is the objective of a research program sponsored by the Air Force Office of Scientific Research at the National Bureau of Standards.

Fiber-Reinforced Composites. NBS is cooperating with NASA's-Langley Research Center, the University of Illinois, and several manufacturers of composites to study the basic failure mechanisms in composites and to develop tests that measure their resistance to crack growth. The use of fiber-reinforced composites in aircraft bodies substantially reduces the overall weight, thereby allowing an increase in fuel or payload. However, the development and growth of cracks in the polymeric material binding the fibers together is a major concern. This program has established guidelines for laboratory tests that measure the resistance of composites to such crack growth. The use of toughened matrix polymers to increase the fracture resistance of their composites also was studied. Based on these results a relationship important in the design and fabrication of improved materials was established between the polymer toughness and the composite toughness.

Measurement Services

Antenna Performance. NBS assisted NASA in defining the design of an advanced antenna measurement facility for the NASA Lewis Research Center. The new facility will enable NASA to measure the performance of large antennas (about 40 feet in diameter) with operating frequencies to 60 gigahertz for such spaceborne applications as satellite communications. The large size and high frequency capability of this new facility will support the development and evaluation of high performance antennas with such special characteristics as very high directivity for sending the strongest signal to the desired location, very low sidelobes for reducing interference with adjacent communication systems, and multiple beams for transmitting a signal simultaneously to separate locations.

Thermoacoustic Refrigeration. Various sensors used in spacecraft often require refrigeration at temperatures below 150° to improve their sensitivity. NBS is studying the feasibility of a new thermoacoustic refrigeration method to provide high reliability, low temperature refrigeration for spacecraft. The new refrigerator device has no moving parts at low temperature, no orifices to plug, and no valves on the room-temperature compressor. Three different concepts for this device were studied and compared; a demonstration model is anticipated late in 1985.

Surface Roughness. NBS is developing an optical instrument to measure the surface roughness of aircraft models that will be used in the new National Transonic Facility wind tunnel. The new facility will simulate air flow conditions around planes flying at the speed of sound or slightly faster. Under these extreme air flow conditions, the surfaces of aircraft models must be very smooth for the simulation to yield accurate results. The NBS optical instrument, to be used in the shop where the model aircrafts are produced, will detect roughness by measuring the light scattered out of a laser beam illuminating an area on the surface.

Heat Transfer. NBS is conducting theoretical heat transfer studies on the behavior of liquid oxygen and liquid hydrogen in low-gravity environments such as those experienced on the space shuttle and the proposed space station. Computer simulation of the effects of low-gravity on heat transfer processes in liquids will provide a basis for more accurate estimates of the quantity of fuel remaining on board the space shuttle and will thus provide improved mission planning. Results for space-based storage tanks will be used in planning orbital and deep space missions associated with a space station.

Calibration Services

Space Telescope Spectrograph. NBS is calibrating a wavelength standard for the High-Resolution Spectrograph (HRS) which will make it possible to identify a discrete spectral feature as coming from a particular chemical element and to know to an accuracy of 1 km/sec or better how fast the material forming that feature was moving. The HRS, to be the most powerful spectrograph used in space, is one of five instruments on the Hubble Space Telescope, an astronomical satellite that will be launched in 1986. Spectral features, seen as broad, single features on previous astronomical telescopes, will be resolved into a multitude of discrete features on this instrument.

Ultraviolet Radiometry. The improved Spectrometer Calibration Facility at the NBS Synchrotron Ultraviolet Radiation Facility (SURF II) was used for further pre-flight calibrations of the Solar Ultraviolet Spectral Irradiance Monitor (SUSIM) experiment of the Naval Research Laboratory. Periodic evaluations and calibrations of the onboard deuterium lamps, which act as secondary in-flight standards, were completed in 1984. The flight and sister lamps were selected after exhaustive tests. NBS also performed extensive calibration work with the Space Telescope Optical Simulator (STOS), designed and constructed by the Martin Marietta Aerospace Company, using laboratory tests of Pt-Cr-Ne hollow cathode lamps and rf-dimer rare gas lamps. These lamps are to be flown on the Faint Object Spectrograph (FOS) of the Space Telescope as secondary vacuum ultraviolet irradiance standards. The lamps were mounted in the STOS and extensively evaluated in preparation for calibrating the Faint Object Spectrograph before launch.

Consultation Services

Computer Software. NBS continued, in 1984, to provide technical assistance to NASA in the development and management of software for NASA's Space Station project. Because of the greater demands for cooperation among NASA field centers, this program requires a new approach to managing software. NBS is helping NASA establish a program of software support activities which includes guidance, training, and information services.

Fire Safety. NBS is working with the NASA Lewis Research Center to develop a method for evaluating fire safety design proposals using equivalency concepts for various NASA facilities. NBS is developing a Life Safety Evaluation System (LSES) for comparing the safety level of proposed design with the objective level prescribed by NASA. Initial efforts in 1984 involved visits by NBS staff to various NASA facilities to identify fire safety features. Analysis of these features will determine those which control the level of fire safety in general purpose buildings. Coordination conferences between NASA and NBS were held in October 1984. When completed, the LSES will enable NASA to meet life safety objectives at minimum cost.

Space and Atmospheric Research

Agricultural Monitoring (AgRISTARS)

Satellite data are being processed routinely into quantities useful for agricultural monitoring. Daily estimates of solar radiation incident at the surface maximum and minimum temperature, and vegetation indices are being evaluated for accuracy and usefulness in crop models and assessment of abnormal weather events affecting crops.

Procedures to estimate 24-hour precipitation amounts from satellite data are being implemented on interactive computer systems. These techniques allow a meteorologist to look at cloud temperature and cloud type on a TV screen and use that information to retrieve rainfall amounts for areas where there are no conventional data. This will be useful over agriculturally important parts of the world where there are few routinely reported weather data.

Meteorology

Precipitation. During 1984, work continued on refining techniques for precipitation estimates for convective extratropical cyclones and tropical cyclones. In addition, a shortrange forecasting technique was developed for experimental satellite-derived heavy convective rainfall. Also, a study of the characteristics of eastern United States and convective flash flood events in the GOES imagery was completed.

Representatives from NOAA and NASA have begun discussions concerning a joint effort to develop special purpose automatic convective cloud detectors and tracking techinques for use with rapid scan GOES data. One of the products would include an immediate "first-guess" of precipitation accumulation based on a fully automatic technique to estimate precipitation.

Hurricanes. The Hurricane Research Division (HRD) is part of NOAA's Atlantic Oceanographic and Meteorological Laboratory (AOML). During 1984, HRD continued to use satellite and other remote-sensing data and satellite communications facilities to support its hurricane research activities.

HRD is conducting a joint research program with the Development Laboratory of NOAA's National Environmental Satellite, Data, and Information Service. The goal is to determine the feasibility of using visible infrared spin-scan radiometer (VISSR) atmospheric sounder (VAS) data to improve the accuracy of operational numerical hurricane forecast models in a real-time mode.

Tropospheric deep-layer mean (DLM) winds, derived from the VAS data, are used to enhance the large-scale DLM wind analysis of SANBAR, the National Hurricane Center's (NHC) operational barotropic hurricane-track forecast model. The anlaysis scheme of the SANBAR model has been modified to allow for the incorporation of the VAS-derived winds (VDW). For each forecast case, the DLM winds initially are calculated from the VAS data over an area that is centered on a tropical cyclone. The VDW's then are combined with the analysis first-guess field and also are used as station data at selected geographical locations.

Test forecasts have been made, based upon HRD's modified analysis package, with and without the VDW data, for a number of 1982 and 1983 storm cases. These tests have demonstrated the potential for improving the accuracy of the SANBAR model's hurricane-track forecasts. Additional modifications, to optimally incorporate the VDW data in the model's analysis scheme, are being tried by HRD.

The communications capabilities of NOAA's Orbiting Satellite System were employed in support of HRD's 1984 Hurricane Field Program. On October 11, HRD conducted its planetary boundary-layer experiment in Hurricane Josephine. Surface pressures, surface winds, and ocean responses were measured concurrently by an array of sensor systems positioned within the storm area. These instruments consisted of a line of NOAA Data Buoy Center (NDBC) drifting buoys, deployed ahead of the storm by U.S. Air Force weather reconnaissance aircraft; a stepped-frequency microwave radiometer, located on the NOAA aircraft that overflew the NDBC buoys; and airborne expendable current profilers (AXCP), which measured changes in the ocean's thermal structure and current, with depth, in response to the moving storm.

Data from the NDBC drifting buoys were transmitted to Service ARGOS (in France) via the NOAA-6 and NOAA-7 orbiting satellites. Through facilities established at NHC and HRD, the buoy data were accessed by computer and made available to hurricane forecasters within about 3 hours of collection. These data were used in the preparation of NHC's surface analyses.

This was the first such use of drifting buoys and only the second time that AXCP's were positioned in a hurricane. In addition, a side-looking airborne radar provided observations of the storm's directional wind properties.

An automated technique for obtaining hurricane intensity has been developed. The method uses the infrared temperature of the edge of the storm and the cold temperature around the eye to calculate storm intensity. The technique has been programmed on a man-machine interactive computer system, enabling the hurricane analyst to compute hurricane intensities in real time at 1-hour intervals. The system, tested operationally in September 1984 on Hurricane Diana, showed good correlation with intensity estimates derived from reconnaissance aircraft.

Ocean Thunderstorms. A study using satellite and conventional data has determined many of the characteristics of thunderstorms that form in the vicinity of the Gulf Stream current. Situated just off the East Coast of the U.S., the Gulf Stream is an important feature to the fishing and maritime industries. Guideliness were developed to assist meteorologists in preparing short range marine and aviation thunderstorm forecasts for the Gulf Stream.

Solar Physics

Gravitational Waves. Scientists at the National Bureau of Standards are exploring the feasibility of a laser experiment to detect gravitational wave pulses in space. The detection of gravitational wave pulses with periods of minutes to hours will provide an entirely new way of studying events in the universe involving very large masses. These events include collisions of massive black holes, both now and during the early history of the universe when galaxies were forming. Black holes are thought to exist at the centers of many galaxies and probably provide the energy source for quasars.

Planetary Systems. NBS is developing ultra-sensitive techniques to measure low light flux to a precision of 1 part in 100,000 for observations lasting several days. These measurements are an effort to discover planetary systems outside of the solar system to characterize oscillations in stars. Distant planets orbiting a star should be detectable by the way the light from the star is blocked off when the planet passes the line of sight between the star. In an experiment to be attempted at the Lick Observatory, the highly stable and sensitive detectors developed by NBS will look for small changes in the faint radiation coming from various stars as the characteristic signature of a planet's passage. The same capability also will be used to measure brightness variations in certain stars to elucidate their internal dynamics.

Planetary Atmospheres

Earth's Atmospheric Chemistry. Through cooperative agreements with NASA and the Chemical Manufacturer's Association, NBS scientists conducted research designed to elucidate the chemical dynamics (reaction rates and mechanisms) of gas phase processes selected for their importance in atmospheric modeling. Results of the NBS studies advance understanding of various atmospheric phenomena, including the effects of natural and anthropogenic emissions on the stratospheric ozone layer, the atmospheric radiation budget (greenhouse effect), and acid precipitation in the troposphere. While homogeneous atmospheric chemistry involves the interactions of numerous free radical and stable species, its study has been facilitated by a subdivision into several reaction subcycles whose elementary steps often can be detailed through individual laboratory studies.

One NBS effort in 1984 was on one such class of reactants, HO_x. Most notable, this included the radicals OH and HO_2, both of which play an important role as reaction chain carriers in the aforementioned atmospheric areas as well as in combustion systems. NBS scientists refined current measurement technologies for studying HO_2 reactions (primarily with other free radicals). Additional efforts concentrated on applying state-of-the-art diode laser spectroscopy to measurements of such radical transients at very low concentrations. Other spectroscopy involved measurements for HCL, HF, the NOx family of compounds, and the long-lived sulfur-containing species COS.

Ozone Concentration Measurements. NBS completed the program of measurement of the ultraviolet absorption cross-section of ozone necessary to obtain the concentration of ozone in the earth's atmosphere. These data cover the wavelength range 240 to 340 nm (Hartley and Huggins Bands) and the temperature range 200 to 300°K, and are needed for accurate analysis of atmospheric total ozone and ozone profile observation. Application of these new cross-sections to observational data from satellites and from ground-based (Dobson) stations has greatly improved the accuracy and consistency of the results. The NBS cross-section is expected to be adopted by the World Meterorological Organization (WMO) as the reference data set for the reduction of atmospheric ozone observations.

Outer Planets and Moons. NBS continued its long-term effort to determine the far-infrared spectra of significant gaseous and liquid constituents of the outer planets and their moons. A theory was developed that describes the far-infrared spectrum of a liquid of diatomic molecules, such as liquid nitrogen, and which provides a simple interpretation of the collision-induced translational band shape and its density dependence. Furthermore, a comprehensive review of 10 years of careful experimental and theoretical work verified that a coherent description of collision-induced processes in atomic liquids now is available. This is particularly significant now that considerable efforts have been initiated to study collision-induced processes that occur in the more complex molecular fluids. Work has begun on the major constituents of the atmosphere of Titan.

Stellar Atmospheres

Solar Activity. In analyzing data obtained from the Solar Maximum Mission satellite, an NBS scientist discovered rapid changes in the ultraviolet emission from bright sites in active regions of the solar atmosphere. The data suggest that the spectrum of heating responses extends all the way from flares and relatively large amplitude, sustained bursts down to smaller, short-lived brightenings. These results are of considerable significance in discussions of overall energy input and heating of the upper solar atmosphere.

Stellar Spectroscopy. Spectroscopic studies of ultraviolet emission lines can provide sensitive probes of the plasma properties of stellar atmospheres. NBS has pioneered techniques for deriving these properties from analyses of collisionally excited ultraviolet resonance lines observed with the International Ultraviolet Explorer (IUE) satellite. In 1984, NBS scientists analyzed an excellent high-resolution spectrum of the star Beta Draconis, the longest exposure yet made with the IUE satellite. From this data they derived a detailed model for the outer atmosphere of this star, which is nearly an order of magnitude less dense than the Sun.

Aeronautical Programs

Aeronautical Research. With the use of an integrated surface and remote sensing network, NOAA's National Severe Storms Laboratory in Norman, Oklahoma, continues to study weather-related hazards to aviation, space shuttle, and the public. Lightning discharges from cloud-to-cloud and from cloud-to-ground, their polarity, and other physical characteristics are receiving increasing emphasis while turbulence, wind shear, hail, and downbursts are being more effectively studied with improved theoretical and observational tools. The observational network consists of weather radar, dual-Doppler weather radars, automated surface observations, rawinsondes, a 444 meteorologically instrumented tower, satellite, lightning location systems, and aircraft. The detection, identification, and characterization of the hazards for warning and accident prevention purposes, as well as the investigation of precursors that may be used in the forecast of these hazards, are included in cooperative projects with NASA, FAA, and DOD. In conjunction with the multiagency Next Generation Radar (NEXRAD) Joint Systems Program Office (JSPO), techniques for data acquisition, processing, and display of aviation weather hazards are being investigated. Development of siting criteria and operating techniques for effective utilization of the Doppler weather radars are being developed to service aviation and public interests.

Department of Energy

The Department of Energy (DOE), as did its predecessors (Energy Research and Development Administration and Atomic Energy Commission), has the responsibility for advancing the technology of nuclear space power systems and the development, fabrication, and delivery of compact, reliable and safe radioisotope thermoelectric electric power systems to meet the requirements of NASA and DoD for space and other special applications. Radioisotope thermoelectric generator (RTG) power systems provided to NASA by DOE over the past two decades have met effectively power and reliability requirements for the Nimbus, Apollo, Pioneer, Viking and Voyager NASA programs. Advanced RTGs are essential power systems for both contemporary missions such as Galileo and Ulysses, scheduled for launch in 1986 and future NASA deep space planetary missions, planned for the 1990's. Higher power nuclear space power systems, beyond the practical range of RTGs and spanning the power range of 1 to 100 + KW (electrical), are in the planning or initial stages of development. Together with the MOD-RTG, these isotopic or reactor powered systems are directed toward prospective NASA and DoD requirements of the 1990's.

Space Nuclear Power Systems

Research and development in the Nuclear Power System Program provide safe, compact, and environmentally acceptable energy systems to Federal agencies for earth-orbital and interplanetary space missions, as well as for other special-purpose applications. The program in 1984 consisted of three major projects: (1) the static outer-planetary radioisotope thermoelectric generator (RTG) project, developing RTGs for NASA's Galileo spacecraft, to be launched to Jupiter in 1986, and the Ulysses (formerly International Solar Polar Mission) spacecraft, to be launched in 1986 to study the Sun; (2) the space reactor technology program (SP-100); and (3) advanced power system technology.

Radioisotope Thermoelectric Generators

The United States has used 34 RTGs, developed by DOE and its predecessors, as electrical power supplies in 19 space systems since 1961, including navigation and communication satellites launched by DoD and the Nimbus, Apollo, Pioneer, Viking, and Voyager spacecraft launched by NASA. These RTG's have encompassed six design concepts spanning beginning-of-mission power ranges from 2.7 to 159.2 watts of electricity. The performance of these generators has demonstrated that nuclear power sources can be engineered safely and reliably to meet or exceed power level and mission duration requirements for a wide variety of space missions.

In each of the past RTG designs, DOE has attempted to improve generator performance, efficiency, and specific power (electrical watts per pound) in order to enhance the objectives of the mission. This has led to improvements in the technology of thermoelectric materials, from the lead telluride (PbTe) used in the first five RTG designs to the silicon germanium (SiGe) used in the MHW-RTG and the RTG's being built for future space missions.

In 1984, research and development continued on the fabrication of thermoelectric converters for qualification and flight-unit general-purpose heat source (GPHS) RTGs to be used in an advanced silicon-germanium generator for the Ulysses and Galileo Missions. The 55.5-kilogram GPHS-RTG is designed to provide a minimum of 285 watts of electricity, with a fuel loading of 4,410 thermal watts. During 1984, thermal and dynamic testing of the qualification unit was completed; and life testing was begun.

The GPHS-RTG electrically-heated full-size engineering unit has been performing normally since its life test was begun in June 1983. The six 18-couple module life tests also are performing normally, some with over 15,000 hours of thermal vacuum operation.

Safety efforts included Safety Verification Testing (SVT) of full-up GPHS fueled modules used to power GPHS-RTG's. Ten SVT tests were completed in 1984. The Updated Safety Analysis Report (USAR) for Galileo and Ulysses missions also was completed in 1984.

The Space Nuclear Reactor Program (SP-100)

The SP-100 program is a cooperative effort jointly sponsored by DoD, DOE, and NASA to develop space nuclear reactor power system technology to enable a broad class of military and civilian space missions. It was established formally on February 11, 1983, by a

Memorandum of Agreement (MOA) involving DoD's Defense Advanced Research Projects Agency, DOE's Office of Nuclear Energy, and NASA's Office of Aeronautics and Space Technology.

The program calls for the three agencies to:

- **Assess and advance the technology for 100 KWe and multimegawatt space nuclear power systems,**
- **Provide engineering development and production systems for users, as warranted, and**
- **Ensure the nuclear safety of all missions.**

To accomplish these objectives, a number of functional requirements for a design reference point have been established. These include required power output (100 KWe through end of life), and design lifetime (7 years at full power; 10 years total system lifetime), mass (less than 3000 kilograms), size (less than 6.1 meters long and able to fit in the space shuttle cargo bay with a payload and booster), and safety (must meet all applicable NASA aerospace safety and DOE nuclear safety requirements). In addition, a major feature must be the ability to grow to higher power levels without major changes in overall design. A three-phase program has been laid out to meet these requirements, including a technology assessment and advancement phase, a ground engineering test phase, and a flight qualification phase.

The objectives of the program during the present phase are to: (1) define missions which need nuclear power and to determine specific characteristics and needs as a basis for design, (2) perform conceptual design studies of attractive powerplant concepts and define the critical technological issues associated with each concept, and (3) conduct experiments and analyses to confirm that presently uncertain areas can be resolved in ways that will not affect the technical or safety feasibility of the concept.

The program is carried out by the SP-100 Project Office, centered at the Jet Propulsion Laboratory (JPL). The NASA Lewis Research Center (LeRC) and the Los Alamos National Laboratory (LANL) provide major support to the project office in the areas of aerospace technology and nuclear technology, respectively. The work of the SP-100 Project is organized into four major elements:

(1) System Definition Element—Earlier in 1984, the program completed its initial 9-month effort by a number of industrial contractors to produce a careful evaluation of potential candidates. Two concepts selected were: a fast flux liquid metal cooled reactor coupled to a thermoelectric power converter, and a fast flux in-core thermionic reactor/power conversion system. In addition, it was decided to investigate a low temperature fast flux liquid metal cooled reactor coupled to a Stirling engine conversion system.

(2) Safety—At this stage of the SP-100 project, an important objective is to apply as much of the prior experience as possible to the decision-making process. This includes the development of preliminary design guidelines and criteria.

(3) Mission Requirements and Analysis Element—Three major generic missions categories have been identified as probably the first users of space nuclear reactor power. These are communications satellites for both commercial and military use, radar surveillance and remote sensing satellites for civil and military applications, and a power system to support manufacturing and other aspects of a developing space station. Of these, the military space radio is the most likely first application.

(4) Technology Element—Significant progress has been made in many key technology areas. For example:

- Fabrication of a 25 KWe free piston Stirling test unit.
- Fabrication and test in a reactor environment of thermionic diodes to demonstrate the potential for 7-year life.
- Progress in high-temperature thermoelectric materials with a figure of merit in excess of 1.0 × 10.
- Compatibility of reactor construction materials and reactor coolants.
- Reestablishment of the ability to fabricate UN fuel elements which has been reestablished and an ongoing effort now underway to demonstrate the capability to fabricate refractory metal fuel pins.
- Fabrication and life test of refractory metal heat pipes.

A major effort is underway to develop a test plan for the next phase of the program. This plan is to be established at the time the decision on phase II is made, which will include the selection of a site for the conduct of the ground test of the reactor system. Preliminary ground engineering test program guidance and schedules were issued to the potential test sites. A draft site selection plan is to be completed and developed concurrently with potential options for the scope and content of the ground test program.

Advanced Power System Technology

Significant progress continued in 1984 in the development of a new RTG concept, the modular isotopic thermoelectric generator (MITG). DOE completed fabrication and began performance-testing eight MITG test modules; and the test data will be used to determine further development of this new concept. Design of a ground demonstration system using the MITG approach also began in 1984, and program plans call for fabrication of thermoelectric modules for assembly of the ground demonstration system in 1985, and testing in 1986.

The MITG promises substantially higher specific power (electrical watts per pound) for future space missions than provided by the present RTGs, with no reduction in safety and with increased reliability. The basic design will be adaptable for many space uses, since the power output can be scaled in 20-watt increments by varying the number of generator slices (identical sections of the standard design), usually without any major design changes. It also permits performance checking of individual thermoelectric modules in the assembled converter and replacement of any that are deficient. Thus, it should be more economical to produce because of modular, scalable, and flexible characteristics.

Advanced technology developments at Oak Ridge National Laboratory, initiated in 1984 in support of the MITG-RTG system, include the following three activities:

(1) State-of-the-art NDT (nondestructive testing) methods were evaluated and adapted to the inspection of the multicouple type thermoelectric module, the basic power conversion building block for the MITG generator, and module subassemblies.

(2) An iridium DOP-26 alloy process improvement activity directed toward improved product yield and quality was initiated. The DOP-26 iridium alloy sheet is the fuel clad material employed in the GPHS.

(3) Also, a CBCF (carbon bonded carbon fiber thermal insulation utilized in the GPHS module) process development program was undertaken. This program is directed toward accommodating new raw materials and improved process controls.

Nuclear Test Detection

The DOE designs and develops spaceborne nuclear detector systems used to monitor adherence to nuclear test ban treaties. Support for this national mission consists of supplying optical and radiation detectors flown as secondary payloads on DOD and NASA systems. These satellite systems enable worldwide surveillance for nuclear testing in the Earth's atmosphere as well as outside the atmosphere.

The DOE national laboratories design, develop, fabricate and test the various detection systems flown on the DoD and NASA satellites. A major element of the DOE program in 1984 was a research and development effort to provide increased radiation hardened detector systems. Overall objectives of the DOE satellite nuclear detection program continued to be improvement in sensitivity, coverage, and data processing techniques for distinguishing background signals from nuclear events to prevent false alarms. As in 1983, the DOE delivered a number of detection systems in 1984 for space monitoring.

Department of the Interior

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of the nationally owned public land and natural resources. This includes fostering the wisest use of land and water resources, protecting fish and wildlife, preserving the environmental and cultural values of the national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses energy and mineral resources and works to assure that their development is in the Nation's best interests. The Department also has a major responsibility for American Indian reservation communities and residents of Island Territories under U.S. administration.

The Department frequently relies on data acquired by satellite and aircraft sensors to inventory and monitor vast, often inaccessible areas and maintains an active program of research and technique development in remote sensing and digital spatial data technology. Innovative techniques have been developed by Department scientists and resource specialists for merging the results of remote sensing analysis with other types of data. This report of 1984 activities includes several examples of digital data base development and application to Department resource management problems. Interior scientists and resource managers are aggressively developing and utilizing remote sensing, digital cartography, and geographic information system technologies, and the Department was recently assigned the responsibility of coordinating digital cartography activities for the Federal government.

Bureaus and agencies of the Department of the Interior participating in remote sensing and digital data applications during 1984 included the Bureau of Indian Affairs, Bureau of Land Management, Bureau of Mines, Bureau of Reclamation, National Park Service, Office of Surface Mining Reclamation and Enforcement, U.S. Fish and Wildlife Service, and the Water Resources, Geologic, and National Mapping Divisions of the U.S. Geological Survey.

Remotely Sensed Data Acquisition and Processing

The Geological Survey continues to use the Earth Resources Observation Systems (EROS) Data Center to maintain archives on Landsat data and handle the processing and distribution of such data for the National Oceanic and Atmospheric Administration. During 1984, 35,000 Landsat Thematic Mapper (TM) and Multispectral Scanner (MSS) images were added to the archive, and approximately 38,000 film and digital products were generated and distributed to worldwide users.

The Geological Survey side-looking airborne radar (SLAR) program continued in 1984 with the award of a contract to acquire SLAR data of approximately 360,000 sq. km. in the conterminous United States. Through this program, which began in 1980, partial or complete SLAR coverage has been made of 33 States, including Alaska (approximately 1,340,000 sq. km. of areal coverage). These data aid both private-sector and Government scientists and managers in studies of energy and mineral resources and in assessing Earth hazards. In addition, the Geological Survey has supported more than 60 studies on the geologic, hydrologic, cartographic, and engineering applications of SLAR data.

The goal of obtaining complete, first-time high-altitude photographic coverage at uniform scales of the conterminous United States has nearly been achieved through the National High Altitude Photography (NHAP) Program. The program began in 1980 as a cooperative effort by 12 Federal agencies. To date, the Geological Survey, acting as the lead agency, has contracted for coverage of 95 percent of the conterminous United States; over 75 percent of the photography is now available. During the first coverage cycle, 1:80,000-scale black-and-white and 1:58,000-scale color-infrared aerial photographs were acquired in blocks of 1° latitude and 1° longitude during the dormant season. The cooperating agencies met in April 1984 and developed a 6-year plan for the second NHAP program. New photography will be acquired during the growing season by state units. There is no planned change in the film types and scales. Participating agencies are expecting the follow-on program to meet their continuing requirements for resource and environmental management.

Digital Data Processing and Analysis

Digital Data-Base Development and Applications

The Geological Survey's National Mapping and Geologic Divisions have continued development of a data base for Alaska. Surface ownership data from the Bureau of Land Management's Alaska Automated Land Record System are being converted to digital form and combined with information on mineral resources. Information on subsurface ownership and restrictions to mineral entry also are derived from the Bureau of Land Management system. The system is designed to answer questions regarding status and availability of minerals for development on Federal lands. Both tabular and graphic products are being generated.

In 1984, the National Park Service used Landsat and aircraft MSS data, as well as Landsat TM data, to develop digital data bases for several National Park System units. Landsat MSS data and digital terrain data were used to map vegetative land cover in North Cascades National Park and to derive fire fuels models for fire management. Aircraft MSS data continued to be used in 1984 to develop a computerized geographic information system for Yosemite National Park. A primary use of this system will be in fire management. The completed system will allow the park manager to integrate predictive models of fire behavior with actual park resource values (for example, vegetation, wildlife, and historic and archeological sites) in order to determine optimum fire management strategies. Digital data bases also are being developed for major park units in the National Capital Region using a combination of Landsat TM data, aircraft MSS data, and color-infrared aerial photographs.

During 1984, digital data bases were prepared for 160,000 sq. km. of land in the Arctic, Kanuti, and Yukon Delta National Wildlife Refuges in Alaska as part of a cooperative program between the U.S. Fish and Wildlife Service and the Geological Survey. These data bases will be used to develop comprehensive conservation plans for these refuges as directed by the Alaska National Interest Lands Conservation Act of 1980. Data bases now exist for 10 refuges covering more than 240,000 sq. km. of land in Alaska. The main components of the data bases are vegetative cover derived from Landsat MSS data, and elevation, slope, and aspect derived from digital terrain data.

The Bureau of Indian Affairs and the Geological Survey are using a previously developed digital data base with processed Landsat data on the Fort Berthold Indian Reservation, North Dakota, to assess land potential for irrigation. Digital data bases also are being developed, using remotely sensed data, for the Hopi and Papago Indian Reservations, Arizona. The Hopi project uses data in a geographic information system to show spatial effects of management influences on semiarid lands. Time-series analysis is being investigated using Advanced Very High Resolution Radiometer data to monitor vegetative growth and range utilization on the Papago Reservation.

The Bureau of Reclamation also is analyzing remotely sensed data and entering the results into digital data bases. For example, maps of submersed aquatic vegetation were produced for national wildlife refuges along the James River in North Dakota as part of environmental studies for the Garrison Diversion Project, North Dakota. These data were interpreted from aerial photographs and entered into a digital data base for each individual refuge.

The Geological Survey's National Mapping Division and the South Dakota district of the Survey's Water Resources Division used registered spatial data sets to obtain a more complete description of the hydrologic cycle in the Black Hills of South Dakota. Topographic, planimetric, hydrologic, geologic, and land cover data were prepared as geometrically registered data sets. Effective procedures for automated delineation of drainage lines and drainage basins with digital elevation data were developed as part of the project. Several parameters were automatically calculated, including flow direction, area, and the linkage tolerances necessary to include closed (noncontributing) basins. Subsequent measurement of a selected group of drainage basin characteristics has been made to prepare a statistical model for streamflow and basin characteristics of the full study area.

A digital vegetation/land cover data base was developed by the U.S. Fish and Wildlife Service for the States of Wyoming and Montana. A map was prepared by manually interpreting 1:1,000,000-scale Landsat MSS color-composite images, digitizing the intepretations, and then entering the data into a digital data base. The data will be used by field offices for wildlife habitat assessment. This approach permits the development of a uniform data set over a large geographic area.

Landsat Thematic Mapper Data Analysis

The Landsat TM imaging system provides new and much more comprehensive data than the data collected during the past 10 years by the Landsat MSS system. A major challenge in working with TM data is to process and analyze efficiently the much larger volume of data resulting from the TM's higher spatial resolution and the increased number of spectral bands. Geological Survey scientists have used a variety of processing techniques on TM data over several sites to (1) reduce the amount of data to be processed and analyzed, (2) digitally process data from small sub-areas to improve the visual appearance of large-scale products or to merge image data having different resolutions, and (3) evaluate and compare the information content of the different three-band composite images that can be made using the TM data. Results indicate that, for some applications, the added TM spectral information (compared to MSS data) is even more important than the TM's increased spatial resolution.

Information Systems Development

The Geological Survey's National Mapping Division signed a cooperative agreement in 1984 with the National Aeronautics and Space Administration's (NASA) Goddard Space Flight Center to develop a Land Analysis System, a comprehensive geographic and spatial data processing system. System objectives include: (1) development of a broad array of algorithms for processing remotely sensed data and for statistical analysis, (2) development of the capability to handle a variety of data formats and products, and (3) installation of these capabilities in transportable software to permit utilization on a variety of computer systems. The first phase of software for the Land Analysis System was released in October 1984.

Image Processing Workstations

The transition of the Geological Survey's Remote Information Processing System (RIPS) from a research environment to an operational capability continued. A baseline software package was released to make the system more useful for specialized applications. This package includes 69 applications programs, 100 support routines, and more than 500 pages of documentation. The first RIPS users conference was held in 1984 and led to the development of additional capabilities and recommendations for system improvement. Approximately 80 RIPS workstations are in use at Federal, State, and university locations, and the workstations now are available on a commercial basis.

The Geological Survey also has developed the Mini-Image Processing System (MIPS) as an office research and development digital image processing system, with potential of use in a field environment. The main objective in designing MIPS was to assemble a relatively inexpensive system powerful enough to be a standalone system. The program documentation, video display, screen formatting, and user prompting modifications recently made to MIPS have greatly improved its efficiency and ease of use.

Monitoring the Environment

Hydrologic Monitoring

Approximately 1,400 Geological Survey hydrologic gaging stations are now equipped with automated instrumentation that provides for data transmission using the National Oceanic and Atmospheric Administration's Geostationary Operational Environmental Satellite (GOES) for data relay. The Survey operates the telemetry at 1,000 of these stations for Federal agencies such as the Corps of Engineers, Bureau of Reclamation, and National Weather Service, and for State and local cooperators. The data transmissions are received from the satellite relay at nine direct-readout ground stations operated by the Survey. Data are transmitted automatically from the ground station computer controllers to host computers for data computation, storage, and dissemination over the Survey's nationwide Distributed Information System. Satellite telemetry provides near real-time data for river forecasting, reservoir management, hydropower generation, and irrigation and water control.

The Bureau of Reclamation developed techniques in 1984 for monitoring certain water quality parameters on inland lakes and reservoirs using satellite and airborne multispectral scanners, and limited ground reference information. These techniques now are being used operationally on Bureau reservoirs in the western United States. In addition, portable hydrometeorological monitoring stations, which transmit data hourly through the GOES system, also support such diverse activities as wind energy research, high-elevation precipitation measurement, and reservoir and stream monitoring.

Land Cover Inventories

The use of satellite and aircraft image data has become common for inventory of land resources on Bureau of Reclamation projects. Land cover features have been mapped and digitized for a variety of studies including wildlife habitat, agricultural crop patterns, hydrology, irrigation consumptive use, and geology. For example, a cooperative study has been completed between the Bureau and the State of Wyoming to apply remote sensing techniques to assess the beneficial consumptive use of water in the upper Green River Basin. A practical technique was developed to apply both satellite images and aerial photographs to monitor the extent of irrigated cropland.

The U.S. Fish and Wildlife Service has been evaluating the accuracy, precision, and cost of producing land cover maps from different types of remotely sensed data. Three different mapping techniques were evaluated for the shale-oil-rich Piceance Basin, Colorado: (1) supervised classification of Landsat MSS digital data; (2) visually interpreted Landsat MSS 1:250,000-scale false-color composite images; and (3) visually interpreted 1:24,000-scale color-infrared aerial photographs. Preliminary results indicate that interpretation of color-infrared aerial photographs is most effective for producing maps with the detail and accuracy required.

The U.S. Forest Service cooperated with the Geological Survey in Alaska to produce land cover classifications from digital processing of Landsat and digital elevation model data for use in one of four sampling phases designed to estimate statewide acreages of land cover types and biomass. Forest Service personnel used digital analysis equipment at the Survey's EROS field office in Anchorage to complete a land cover classification for the Tanana River Basin. Eight-hectare sample blocks were located systematically at the intersections of a 5-km. grid throughout the basin. Data for each sample block were extracted from the area-wide land cover classifications and used to estimate land cover type and biomass. The Forest Service is incorporating these data into a multiphase sampling framework which includes resource estimates from two scales of aerial photographs and ground sample measurements.

Forested Wetlands Mapping

Research was conducted by the Geological Survey to determine the utility of Seasat radar images to map forested wetlands. It is difficult to distinguish forested wetland from dry forest using aerial photographs because photograghs often do not reveal the presence of water below the tree canopies. Images obtained during the summer months of 1978 by Seasat's L-band (23 cm) radar revealed that forested wetland in the Atlantic coastal plain between Maryland and Florida had patterns of high radar reflection. A test revealed that accuracy in image interpretation was significantly higher when the Seasat radar images were used with conventional data types such as aerial photographs and topographic maps than when only conventional data types were used. The potential exists for Seasat radar images to complement aerial photographs in the preparation of wetland maps.

Mine Development and Safety Monitoring

The Bureau of Mines is investigating a composite methodology to construct mine hazard evaluation maps using Landsat data, aerial photographs, and digital terrain data in combination with other geologic, geophysical, and geochemical information from field studies in mining regions. Many researchers have used visual interpretation of satellite images and aerial photographs for geologic lineament analysis to detect potentially hazardous areas before and during mining in underground coal mines. To reduce the subjectivity inherent in visual interpretation of remotely sensed data, the Bureau is using digital processing techniques to identify lineaments from Landsat digital data. An interagency cooperative research project between the Bureau and the Geological Survey has resulted in an automatic lineament mapping method which permits processing the Landsat data to enhance those natural features of interest while suppressing extraneous information. While it is not expected that lineament studies will identify all mine hazards, the remote sensing technique is considered a valuable tool in identifying potential problem areas.

The Bureau of Mines also concluded a contract project to investigate the feasibility of using the GOES system as a communication link to monitor remotely the stability of coal mine waste embankments. Field data from a group of 17 geotechnical sensors installed in an embankment at Montcoal, West Virginia, were transmitted through an unmanned solar-powered data collection platform at the site to a central computer facility in Washington, D.C., via the GOES system. The results from the year-long field test indicated that the reliability and resolution of the data received through the satellite link were excellent. However, due to malfunction of many sensors, no correlations were established between the received data and the ground conditions of the test embankment.

Low-altitude aerial photographs of active surface coal mine areas in the Appalachian and western U.S. coalfields were used by the Office of Surface Mining to monitor active mining areas. Aircraft thermal-infrared scanner images aided in mapping and detecting outcrop and underground mine fires. Landsat images and aerial photographs of alluvial valley floor areas in the western coal States were used to assess and document the impact of mining.

The Bureau of Land Management compared aerial photographs taken in 1951 and 1984 to calculate the volume of pits and mine spoils requiring environmental reclamation in New Mexico. Spoil areas were stereoscopically viewed, contours were digitized, and the resulting data were analyzed to determine the volume change between the two dates.

GEOLOGY

Lithologic Discrimination Studies in Antarctica

The Geological Survey's Geologic Division used computer-enhanced (band-ratio and linear-stretched) Landsat MSS data to discriminate successfully sandstone, granite, felsic igneous, and dolerite units in the dry valleys region, Antarctica. Surficial deposits such as glacial till versus alluvium/colluvium were also delineated based on relative particle size and composition. The Landsat spectral reflectance data were found to be superior to medium-altitude color and color-infrared aerial photographs for reconnaissance geologic mapping of lithology and surficial deposits.

Planetary Studies

Over the past 20 years, the Geological Survey has cooperated with NASA to produce 270 topographic and planimetric maps and 124 geologic maps of 14 extraterrestrial bodies within the solar system. The total area mapped is approximately 1.5 billion sq. km., or about 11 times the land area of the Earth. To date, planimetric mapping by the Survey has included Mercury (45 percent of surface); the Moon (100 percent); Mars (100 percent); the larger satellites of Jupiter (Ganymede and Callisto, 80 percent, and Io and Europa, 40 percent); and the larger satellites of Saturn (Rhea, Iapateus, Enceladus, Mimas, Dione, and Tethys, 75 percent).

As part of this effort, the Geological Survey's Branch of Astrogeology in Flagstaff, Arizona, has completed a series of 140 controlled photomosaics of Mars for NASA. The photomosaics cover the entire planet at a scale of 1:2,000,000 and were made from rectified Viking Orbiter spacecraft images. The photomosaics were designed to support a wide variety of educational and planetary science research activities. Most of the 10,000 images in the mosaics were returned to Earth in 1978 via radio transmission from the two Viking Orbiters.

Scientists from the Geological Survey and the Jet Propulsion Laboratory have been studying Io, the volcanically active moon of Jupiter, which has the greatest surface heat flow in the solar system. Io's heat flow is induced by tidal heating caused by the gravitational pulls of Jupiter and the other large Jovian satellites. Data from the infrared spectrometer on the Voyager 1 spacecraft were used in this study and it was concluded that the heat is transferred primarily through lava lakes of liquid sulfur.

Magsat Data Investigation

The Geological Survey also has been analyzing data from NASA's Magsat. Global magnetic anomaly maps have been interpreted, with an emphasis on the African and South American continents. Procedures were developed for spatial filtering of the gridded total-field Magsat anomaly data. Geologic interpretation revealed that anomalies in the Magsat data correlate with uplifts of specific age and with basins of specific depth. One spatially filtered anomaly trending through South America was interpreted as being characteristic of conventional upwelling in the Earth's mantle. This suggests that a metallogenic province for rift-related mineral deposits may be located along this trend. Interpretation of Magsat anomalies also should be useful in developing models of large-scale crustal processes.

Cartography

Image Mapping

The Geological Survey continues to develop improved techniques for producing Landsat image maps. Advances in image mapping science include the development of innovative techniques for computer processing for enhancement of digital image data, photographic and digital mosaicking, and lithographic printing. Research in 1984 included: (1) implementing software for production of large-area digital mosaics of Landsat data for areas as large as 6° in both latitude and longitude, and extracting individual quadrangles for more efficient image map production; (2) developing methods to prepare map separates for printing directly from digital data; (3) improving digital techniques for geometric correction and image enhancement; and (4) combining Landsat data with other digital data sets, such as elevation data, for analysis in computer-based geographic information systems.

Several new image map products were generated from Landsat TM, MSS, and Return Beam Vidicon (RBV) data during 1984:

- The following color image maps were prepared using TM data:

  Washington, D.C., and vicinity—1:100,000-scale TM image map covering a 1° by 30′ area centered on the Nation's capital, and a graphical display of 24 false-color composite TM images with accompanying statistical analysis and ranking of the images according to their information content.

  Great Salt Lake and vicinity—1:125,000-scale Landsat TM image map which displays the area in July 1984 when the lake was at its highest level in 111 years. Portions of four Landsat scenes were combined in a mosaic, and contour lines were added to show the elevation and position of the shoreline at various times. This image map will be useful for planning reclamation activities and protective works.
- Image maps from Landsat MSS data were produced at 1:250,000 scale for four standard 1° by 2° quadrangles (Norfolk and Richmond, Virginia; Needles, California; and Tonopah, Nevada). The Geological Survey cooperated with other U.S. and foreign agencies to produce Landsat MSS image maps of portions of Western Sahara, Saudi Arabia, and Central America.
- Black-and-white image maps were prepared at 1:250,000 scale from MSS and RBV data for several quadrangles in Alaska north of 68°N. latitude. Coverage of the North Slope of Alaska is now complete.

Future research will emphasize techniques for merging high-resolution data from new satellite sensors with conventional cartographic and earth resources data sets in digital form for rapid analysis to allow more timely and effective assessment of earth resources.

National 1:100,000-Scale Digital Cartographic Data Base

The Geological Survey is beginning a major new program to create a nationwide digital cartographic data base from 1:100,000-scale maps by mid-1987. This data base will supplement the currently available 1:2,000,000-scale national data base and selected coverage of digital data from 1:24,000-scale source materials. It will provide complete coverage of transportation features (roads, railroads, powerlines, pipelines) and hydrographic features (streams, rivers, water bodies). Implementation of the production process has been facilitated by an agreement between the Survey and the Bureau of the Census to complete a national data base by 1987 for use as the cartographic framework for the 1990 Decennial Census. A pilot project for the entire State of Florida (corresponding to forty-eight 1:100,000-scale quadrangles) was completed successfully. This project enabled the Survey and Census to develop and test new production procedures and software. During 1984, these procedures were implemented, and 385 digital line graph files were completed.

Aerial Profiling of Terrain System

The Aerial Profiling of Terrain System has been under development by the Geological Survey since 1974. It is a precision airborne surveying system capable of measuring elevation profiles across various types of terrain from a Twin-Otter aircraft at flying heights up to 600 m. above the ground. Flight tests of the system in 1984 indicate that accuracy goals of +0.15 m. (vertical) and +0.60 m. (horizontal) were achieved.

The first in a series of application tests was completed to determine the effectiveness of the system for gathering data for Geological Survey earth-science programs. For this purpose, the system was used to determine the horizontal and vertical positions of water wells along the Charles River near Needham, Massachusetts, and to determine the level of the river at over 60 locations. Other tests will establish terrain profiles for measuring the accuracy of several 7.5-minute quadrangle maps and will determine elevations of more than 200 kettle ponds in New England. After completion of these tests, plans are to use the system as an operational earth-science data collection system.

International Activities

Workshops

Geological Survey scientists held two 5-week remote sensing workshops during 1984. A workshop in May for eight scientists from five countries emphasized application of remotely sensed data to geologic and hydrologic resource problems; a September workshop for seven scientists from five countries applied remotely sensed data to vegetation and land use analysis.

Hydrologic Studies

The Bureau of Reclamation has entered into a cooperative agreement with Spain to transfer technology for monitoring reservoir ecology using Landsat MSS data. Bureau scientists are training Spanish scientists and engineers to use techniques which were developed for use on lakes and reservoirs in the western United States.

Landsat and Advanced Very High Resolution Radiometer data are being used to monitor snow-covered areas in gaged drainage basins of the High Atlas Mountains of Morocco. The work is a part of the Moroccan Winter Snowpack Augmentation Project, a cooperative program between the United States and Moroccan governments.

Department of Agriculture

The Department of Agriculture (USDA) is engaged in a broad-based research effort to develop efficient and cost-effective ways to use remotely sensed data from space for ongoing programs to assess agricultural conditions and management of renewable resources.

A pioneer in the use of aerial photography, USDA recognizes the potential of remotely sensed data from space as a valuable source of information for the decisionmaking process in programs and operations. The use of remotely sensed data from space sensors is considered a logical and evolutionary development following the use of aerial photography, long a vital source of information for such diverse USDA activities as forest management, soils mapping, farm conservation planning, and monitoring crop acerage.

This was reflected in 1984 by the continued emphasis given by USDA to its multiagency program for Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing (AgRISTARS). Among the major objectives of AgRISTARS are to monitor crop conditions and to provide more accurate statistics on land use. This program includes research to develop and test various applications of data transmitted from Landsat and polar-orbiting meteorological satellites to Earth. Principal agencies of USDA participating in AgRISTARS are the Statistical Reporting Service and Agricultural Research Service. The Soil Conservation Service also is involved in the program. Other USDA agencies using aerospace remote sensing are the Agricultural Stabilization and Conservation Service, Forest Service, Federal Crop Insurance Corporation, Foreign Agricultural Service and Economic Research Service.

During 1984, USDA continued research on the potential utility of data from the advanced-very-high-resolution-radiometer (AVHRR) sensors aboard the polar-orbiting satellites of the National Oceanic and Atmospheric Administration (NOAA). Studies were undertaken concerning changes in data resulting from atmospheric conditions and distortions that occur as sensors look at the ground from different scan angles (angles of view). Precise measurements of the variations resulting from atmospheric conditions and scan angle have not been possible to date. However, other data characteristics were identified; and several useful analytical techniques have been developed for future use in these and other studies. Preliminary results from other research show relationships between vegetative indices (conditions of vegetation) and changes in temperature indices from day to night. They may prove useful in detecting plant stress. In addition, an improved cloud-screening technique was developed and currently is in use to stabilize vegetative indices for predefined conditions. The Foreign Agricultural Service now is employing the new cloud screening technique in operational image analysis procedures.

New ways to use Landsat Multispectral Scanner (MSS) digital data in forest management is under development by the Forest Service. In 1984, major advances were achieved using such data and other information for forest inventories. Landsat data also are important for the mapping of forest fuels—the materials accumulated on the forest floor that ignite easily and spread wildfires. This information is used in computer-simulated fire-spread models, together with other data such as slope, aspect and weather, to predict wildfire behavior.

The Soil Conservation Service began a pilot test in Oklahoma using remotely sensed techniques to collect data on land cover and land use patterns in support of the 1987 National Resources Inventory. The primary source of data collection will be aerial photo interpretation using high altitude color infrared photography. In addition, digital techniques will be tested using data collected by the thematic mapper of the Landsat 5 satellite.

Assessment of soil moisture conditions prior to planting can provide valuable information on the crops that will perform best under, for example, limited moisture conditions. After the crops are planted, frequent soil moisture mapping would enable farmers to tailor irrigation to a crop's exact needs, thus saving water and energy. Soil moisture readings should also have a major impact on U.S. and world crop production estimates because of the importance of soil moisture to yield.

In the Texas panhandle, the Agricultural Research Service, in cooperation with the Soil Conservation Service, monitored a 10-county area (about 1,000 square miles) with two instruments carried on aircraft: the 4-beam L-band radiometer and the L-band synthetic aperature radar. The data collected now are being processed to generate soil moisture maps that will be compared with conventional maps of soil moisture. The objective is to discover whether reliable measurements of soil moisture can be made before the planting season begins in order to determine which crops will do well under specific moisture conditions.

In October 1984, scientists from USDA's Agricultural Research Service tested highly specialized radar (Shuttle Imaging Radar-B) carried by the space shuttle Challenger to determine its effectiveness in measuring soil moisture. The experiment focused on target farms near Fresno, California; the California State University of Fresno and the University of California's West Side Field Station arranged ground sites for the tests. The California experiment, as well as earlier soil moisture research activities, was a cooperative venture of USDA and the National Aeronautics and Space Administration's Goddard Space Flight Center.

In June 1984 the Federal Crop Insurance Corporation (FCIC) initiated an operational test of the Landsat Emergency Access and Products (LEAP) Program. The LEAP Program was established by NOAA, Department of Commerce, to provide Landsat data, products and services in minimum time to Federal, State and local agencies with the authority and responsibility for protecting lives and property during a civil emergency resulting from a natural or man-made disaster.

The FCIC insures 38 different crops and 17,868 crop programs throughout the United States from losses caused by unavoidable natural hazards such as drought, excess moisture and hail. The test initially was used to determine if timely delivery of Landsat imagery could benefit both FCIC's Acturial Division (underwriters) and Claims Division by improving damage surveys, building data bases for crop insurance rate schedules, and facilitating deployment of field personnel for damage assessment and loss adjustment.

In the 1984 field test, Landsat scenes were selected in Lubbock, Texas, and Glendive, Montana, to compare the 1984 drought effect in those areas to a previous non-drought year. Two additional scenes were requested covering areas of flood or hail and/or wind damage in 1984 in Iowa/Nebraska and Missouri/Arkansas. The final scene selected was Spokane, Washington, to detect possible insect damage.

FCIC field offices are continuing to evaluate the utility of Landsat to imagery to refine crop insurance schedules and more precisely locate and delineate disaster areas. Ground truth, including crop types, planting dates, and crop conditions, is being collected in selected areas to test the efficiency of Landsat.

For the 1985 crop year, the FCIC Acturial and Claims Division plan to expand these tests for the 1985 crop year for winter and speciality crops by using the same ground techniques in conjunction with Landsat multispectral scanners and thematic mapper data.

Federal Communications Commission

During 1984, international and domestic satellite communications networks continued to expand; and new services were introduced employing the lastest technology to serve the demands of a growing market. The International Telecommunications Satellite Organization (INTELSAT) network consists of 17 satellites positioned over the Atlantic, Pacific, and Indian Oceans. Seven new domestic satellites were launched; and orbital spacings between several domestic satellites were reduced to 2 degrees to permit growth of existing systems and the introduction of additional new systems. In 1984, as in 1983, the International Maritime Satellite Organization (INMARSAT) requested proposals from industry for additional maritime satellite capability. INMARSAT has a lease agreement with INTELSAT to provide maritime communications service through 1985 by means of Intelsat V and V-A satellites. Several new specialized satellite systems for mobile and radiodetermination services were proposed. A total of five new commercial satellite systems have been proposed for international services in the Atlantic Ocean Region.

Atlas-Centaur-62 boosted upward from Pad B at Launch Complex, Kennedy Space Center, June 9, 1984, to put in orbit the ninth in a series of two-ton Intelsat V communications for the 108-member-nation International Telecommunications Satellite Organization.

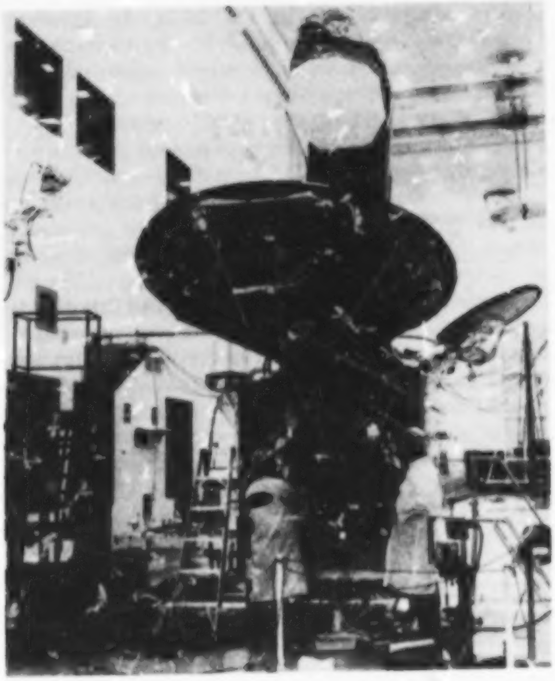
Communications Satellites

INTELSAT

At the beginning of 1984, the INTELSAT global communications system consisted of two Intelsat IV satellites, five Intelsat IV-A's and seven Intelsat V's (an increase of two Intelsat V's). During 1984, the operational satellites were reconfigured in operational zones as follows: 2 IV's, 2 IVA's and 4 V's in the Atlantic Ocean Region (AOR); 2 V's in the Indian Ocean Region (IOR); and 2 IVA's in the Pacific Ocean Region (POR). COMSAT inaugurated its third east coast earth station at Roaring Creek, PA and provided satellite services from its Santa Paula earth station for the 1984 Olympics. The Commission approved 11 new earth station facilities to access the INTELSAT system in the AOR for international (digital) business service. The Commission authorized COMSAT to participate in the construction of five INTELSAT VI satellites to be built by Hughes Aircraft Company.

Domestic Commercial Communications Satellites

In 1984, the domestic commercial communications satellite network increased from 16 to 23 satellites with 18 satellites operating in the 4/6 GHz bands and 7 using the 12/14 GHz bands. Two of the satellites operate in both the 4/6 GHz and 12/14 GHz bands. Four satellites, Westar I, Satcom I, Comstar D1 and D2, have been retired and replaced with higher efficiency satellites. The Commission has authorized the launch and assigned orbital positions for a total of 38 domestic satellites. Estimates are that the 38 locations will be occupied by 1987. In addition, there are currently 85 additional applications on file with the Commission for new domestic satellites. These applications are under review with respect to 2 degrees spacing and consideration for expanding the orbital arc available for assign-



The Intelsat V-F-9 satellite, the last of the V-F series of INTELSAT spacecraft, shown here in the clean room of Hanger AO, being checked out by technicians.

ment. The additional applications consist of a mixture of new satellite applicants, expansion of existing and planned systems, and replacement satellites for existing systems.

In 1983, the Commission ordered the reduction in the orbital separation between domestic satellites in 12/14 GHz bands from 3 degrees to 2 degrees and adopted 2 degrees as the basic, long term orbital spacing criterion in the 4/6 GHz bands instead of the present 4 degrees separation. Upon review, it again concluded that 2 degrees orbital separations in the 12/14 GHz bands are technically feasible immediately with little cost to users, but the cost and difficulties in the 4/6 GHz bands warrant a more cautious approach, combining 3 degrees, 2.5 degrees and 2 degrees spacing. The variable orbital spacing of satellites in the 4/6 GHz bands provides a transition to uniform 2 degrees separations in the future and permits several years for amortizing and upgrading or replacing existing ground stations for the 4/6 GHz bands before all satellites are operated with 2 degrees spacing. The Commission acted on a request by several parties for a partial reconsideration of its 2 degrees spacing plan in the area of improved antenna performance standards, full frequency re-use as related to usable bandwidth, minimum power for 12/14 GHz satellite, and language changes in the rules which clarified protection for earth stations from terrestrial interference. These subjects were addressed; and 2 degrees orbital spacing remains as a viable means for accommodating additional satellite systems. The Commission established an advisory committee as an effective vehicle for obtaining expert technical and operational advice on how to better implement 2 degrees spacing in the 4/6 GHz and 12/14 GHz bands.

The Commission's action on reduced orbital spacing of U.S. domestic satellites does not prevent other Region 2 administrations from implementing their own domestic satellite systems and has reaffirmed its commitment to cooperate fully with other countries in the Western Hemisphere through the frequency coordination procedures of the international radio regulations. The Commission is in the final stages of coordination of domestic satellite systems with the Brazilian satellite system to provide operations with spacings of 1 degrees between satellites. Also, 18 U.S. domestic satellite locations have been coordinated with the INTELSAT systems under the INTELSAT Agreements for both domestic and transborder satellite services.

New technology continues to bring economic benefits and improved services to satellite users. Such new techniques as companded (compressing voice channel for transmission and then expanding the received transmission) frequency division multiplexed-frequency modulation (CFDM-FM) permits up to 2892 voice channels per 36 MHz transponder and companded single sideband (CSSB) permits up to 78,000 voice channels per 36 MHz transponder. The Commission has authorized a digital data transmission service that transmits a low-data-rate spread-spectrum signal (SSS) from 1.2 meter ground station antennas in the 6 GHz band where many data channels are operated simultaneously on a single carrier. An SSS medium digital data system has been authorized that operates with only a single channel per carrier but is capable of operating with presently installed unimproved antennas without affecting 2 degrees spacing.

Direct Broadcast Satellite Service

In January, 1984, each of the eight DBS companies previously granted permits in 1983 to construct Direct Broadcast Satellites (DBS) submitted modifications to their system proposals, as ordered by the Commision, to conform to the parameters established at the 1983 Regional Administrative Radio Conference (RARC-83). The original proposals called for two, three or four satellites to cover the continental United States; the modified proposals uniformly accomplished this "full-CONUS" coverage with two satellites, each satellite covering half-CONUS. Four of these companies now have been granted modified construction permits and launch authority. One is to provide six channels of half-CONUS service from each of two satellites at separate locations; another will provide six channels of half-CONUS service plus four channels of "spot beam" service (serving three limited geographic areas) from each of two satellites at separate orbital locations; a third will provide six channels of half-CONUS service for two satellites located at the same orbital position; and the fourth will provide six full-CONUS signals from one orbit position (with 2 three channels satellites). This last service is expected to be launched in early-to-mid-1986. The others expect their first launch in mid-to-late 1987, with the second launch approximately six months later. All systems will use 200-240 watts per channel. The system using full-CONUS signals and the system using colocated satellites are not provided for explicity in the Region 2 Plan adopted at RARC-83, but computer model analysis predicts that these operations will not impose constraints on the Plan. They are sufficiently flexible to permit adjustment, if necessary. The change of full-CONUS signals without an increase in power output by one company is accomplished allegedly without deterioration in service quality, due to advances in antenna and receiver technology. The remaining four original companies granted construction permits have had their permits cancelled for failure to comply with the terms of those permits.

Three additional applicants, previously placed on a "second-round" cut-off list, have been joined by four more applicants, each proposing delivery of six to sixteen channels from each of two satellites. In addition, two of the permittees currently constructing have requested the assignment of two additional channels per satellite; and one of the original permittees which had put its DBS plans on hold has now requested consideration of a modified DBS proposal for immediate implementation.

Aeronautical

The International Civil Aviation Organization (ICAO) has, in conjunction with INMARSAT, begun to consider how the aeronautical mobile-satellite allocation may be utilized. ICAO has approached INMARSAT to investigate the possibility of shared use of satellite facilities. INMARSAT subsequently specified the inclusion of a small part (1 MHz) of the aeronautical mobile-satellite band in the frequency range to be covered by INMARSAT's second generation satellites for which bids currently are under evaluation.

ICAO has established a Special Council Committee on Future Air Navigation Systems (FANS) to develop the requirements of the aviation community for aeronautical mobile satellite service. The FANS committee met for the first time during 1984.

Maritime

National and international efforts continue towards establishing a future global maritime distress and safety system (FGMDSS). The System will use satellite emergency-position-indicating radio beacons (satellite EPIRBs) for providing initial distress alerting information from ships in distress to shore based rescue coordination centers (RCCs). Present plans envisage satellite EPRIBs operating through the INMARSAT (geostationary) and COSPAS/SARSAT (polar) satellite systems. The FGMDSS is expected to be fully implemented by 1996.

IMO's subcommittee on Radiocommunications (SCR) agreed in principle to recommend to IMO's Maritime Safety Committee that the FGMDSS should be introduced in stages between 1990 and 1996. This represents a significant change in philosophy since originally completion of implementation was expected by 1990. Coordinated trials to evaluate the satellite EPIRB continue. The SCR endorsed the suggestion of Study Group 8 of the International Radio Consultative Committee that INMARSAT should organize pre-operational trials of the 1.6 GHz satellite EPIRB system.

INMARSAT currently has available three satellites to serve each of the Atlantic and Indian ocean regions and one to serve the Pacific. An additional satellite to serve the Pacific area is expected early in 1985. INMARSAT serves about 2800 vessels with the present facilities. INMARSAT is evaluating bids on its second generation space segment with a projected service date to commence service on these satellites in 1988 (1988-1995).

New Satellite Services

On July 12, 1984, in response to a petition from Geostar Corporation, the Commission issued a Notice of Proposed Rulemaking in General Docket no. 84-689, which proposes to implement a radiodetermination satellite system domestically that would allow subscribers to determine latitude, longitude and altitude, and to exchange brief coded messages using inexpensive hand-held transceivers. Geostar requests a spectrum allocation of 33 MHz where the ground-to-space transmissions would be in the 1610.0-1626.5 MHz band, the space-to-ground transmissions would be in the 2483.5-2500.0 MHz band. An additional non-exclusive allocation of 16.5 MHz centered at 5125.0 MHz and 5175.0 MHz also were requested for communications between the satellites and a single computer processing and a control facility. Geostar's use of this spectrum would preclude other uses only within a small radius of the control facility. The 1610.0-1626.5 MHz band is allocated internationally to the Aeronautical Radionavigation Service and Aeronautical Mobile-Satellite Service on a primary, co-equal basis and is reserved for use and development of airborne electronic aids to air navigation. The other bands are allocated to the fixed and mobile terrestrial services and industrial users.

International Conference Activities

The Commission continues to prepare for the World Administrative Radio Conference (Space WARC), the first session scheduled for August 1985. The second session will be held in 1988. The objective of the conference is to guarantee all countries equitable access to the geostationalry satellite orbit and the frequency bands allocated to space services. The Commission Advisory Committee for Space WARC, bringing the non-government participants into the preparations, met from May through December 1984 and completed the majority of its work. This will be transmitted to the Commission early in 1985.

In mid-1984, the Commission began its preparations for the planned 1987 World Administrative Radio Conference (WARC) for the mobile Services. That conference is expected to address the majority of the ITU Radio Regulations concerning the mobile and mobile-satellite services. The Commission released a first Notice of Inquiry in June, 1984, requesting public comment on a list of items for the agenda for that conference. An Advisory committee is expected to be established shortly to assist the Commission in preparing for the conference. A number of on-going domestic activities in the radiodetermination and land mobile satellite areas will have an impact on the U.S. proposals to be developed for the 1987 WARC.

Department of Transportation

Aviation Safety

Aircraft Safety Research

On December 1, 1984, after five years of research and planning, the Federal Aviation Administration (FAA) and the National Aeronautics and Space Administration (NASA) conducted a cooperative "Controlled Impact Demonstration" that simulated a survivable takeoff or landing accident by intentionally flying a four-engine Boeing 720 into the ground. FAA thus was able to collect data on the effectiveness of antimisting kerosene (AMK) and the behavior of various aircraft components and equipment under the heavy stresses of a survivable accident. During the remotely controlled flight, which lasted approximately nine minutes, the aircraft climbed to 2,300 feet before beginning its descent into a prepared impact area at Edwards Air Force Base, California. The flight was flawless until the last few seconds when an unplanned adverse yaw roll altered but did not invalidate the impact scenario.

The postcrash fire, larger than expected, raised questions about the effectiveness of antimisting kerosene, on which research and development had been recommended in 1980 by the Special Aviation Fire and Explosion Reduction (SAFER) Advisory Committee. By the end of 1984, the postcrash fire still was being evaluated, and a final judgment on the effectiveness of antimisting kerosene has not yet been made.

The impact demonstration yielded other results. The test aircraft carried instrumented dummies, high-speed cameras, and more than 350 sensing devices. Aircraft and performance data from the various crashworthiness experiments on board the airplane were transmitted by telemetric link to ground recorders and should be useful in improving future aircraft design, structures, and safety systems. The instrumentation in the B-720 continued to transmit data for 10 minutes after impact. A review of the films of the interior indicated that all seats and simulated occupants remained in place, except for one row of three seats near the break in the fuselage, which dislodged and came to rest in the center aisle. The impact was judged to be survivable.

The FAA also promoted fire safety through rulemaking. In 1984, the agency adopted two new regulations to increase the chances of passengers surviving airline accidents involving fire and smoke. One applies to operators of transport aircraft weighing 12,500 pounds or more and having thirty or more seats and calls for the installation, within three years, of seat cushions that meet new, more stringent flammability standards. The seat cushions will have an outer layer of highly fire-resistant material that will cover the seat's foam core. FAA tests have demonstrated that such seat cushions could delay the onset of "flashover" in the aircraft cabin by as much as 40 seconds, thus providing crucial added time for passenger evacuation. Flashover is the point where vapors trapped near the cabin ceiling will suddenly ignite and spread fire the length of the cabin, consuming oxygen and making survival virtually impossible.

Before flashover occurs, smoke from burning fuel and cabin material can totally obscure overhead emergency lighting and fill the cabin down to near floor level, making it difficult for passengers to see and reach emergency exits. The second regulation addressed this problem by requiring new emergency escape path markings or lighting on or near the floor to help guide passengers to safety. Several types of lighting or markings mounted in locations such as aisle seat frames, armrests, aisle floors, and wall panels can be used to satisfy the regulation's performance standards. The rule requires the operators of large airline aircraft under Federal Aviation Regulation (FAR) Part 121 to install the new markings within two years.

In another fire-safety related action, the FAA issued a notice of proposed rulemaking on cargo-compartment interiors. All aircraft cargo compartments must have a liner constructed of materials that meet the basic requirements set forth in FAR 25 and must be tested in accordance with applicable portions of Appendix F of that FAR. These regualtions had last been amended in 1972. As a result of a 1980 in-flight fire that originated in the aft Class D cargo compartment of a Saudia L-1011 Tristar, which was lined with materials complying with FAR 25, FAA undertook a project to develop a more stringent "burnthrough" requirement for testing cargo lining materials under full-scale conditions. This upgraded requirement was the subject of the proposed rule.

Finally, in March 1984, the agency issued a notice of proposed rulemaking (NPRM) requiring air carriers to install fire extinguishers and smoke detectors in the galleys and lavatories of their large or transport category passenger-carrying aircraft operated under FAR Part 121. The smoke detector system would provide a fire warning to the cockpit or to the passenger-cabin crew. The NPRM also proposed that each lavatory trash receptacle be equipped with a fire extinguisher that discharges automatically whenever a fire occurs in the receptacle. In addition, the notice increased the number of hand-held fire extinguishers located in the cabin of aircraft capable of seating more than sixty passengers. At least two of these would have Halon 1211 as the extinguishing agent. In December 1984, the final rule was sent to the Office of the Secretary of Transportation for executive coordination.

Aviation Security Research

The agency continued efforts to develop improved systems for detecting explosives concealed on passengers, in baggage, or cargo. During 1984, FAA's Office of Civil Aviation Security substantially increased the minimum performance requirements for such detection systems; and, as a result, certain projects that appeared unlikely to yield products capable of meeting the new standards were terminated.

FAA placed increasing emphasis on seeking out new methods of detection. The agency undertook an assessment of state-of-the-art technologies and several feasibility studies in order to identify and evaluate promising alternative techniques. One study evaluated a novel laser opto-acoustic method of detecting fragmented explosive molecules. Another assessed a fast neutron inelastic scattering technique for identifying the element composition of explosives. Methods of detecting flammable liquids carried by passengers also received attention. While the vapor signature of gasoline has been identified, commercial vapor detectors now available appear to fall short of the sensitibity and specificity requirements for aviation security use. The agency will continue work on this project into 1985.

FAA also continued working in more traditional experimental areas of weapon and explosive detection. One is thermal neutron activation, in which explosives are bombarded by neutrons that trigger a nuclear reaction peculiar to the target material, thus permitting its identification. In previous years, this system had been tested at Pittsburgh and Boston airport and showed promise in detecting explosives in sealed containers. In the fall of 1984, FAA tested the system at the United Airlines cargo facility at Chicago's O'Hare International Airport. More than two thousand packages were screened by the system. The results established this concept as the best available for air cargo application. FAA plans additional airport tests for early 1985 to evaluate further the system's effectiveness on checked baggage.

In recent years, FAA has concentrated much effort to develop a device that would routinely detect the vapors of explosives carried by individuals. In 1984, design concept studies were made by FAA on three competing vapor detection technologies. Preliminary results proved promising; and FAA decided to go forward with the development of a prototype system based on a technique known as chemiluminescence.

Another detection device, nuclear magnetic resonance, subjects the molecules of explosives to magnetic fields and pulsed radio frequencies. The characteristic responses of the molecules are captured and displayed. During 1984, FAA field tested this technique at the Dallas-Fort Worth Regional Airport. It also tested and evaluated an experimental digital X-ray system called MAX-E. One objective of this investigation was to determine whether a dual-energy x-ray approach could be employed to differentiate between the elemental composition of explosives and objects commonly found in baggage. Both of these investigations were undertaken to satisfy FAA's original explosive detector performance goals, which they did. However, the test results did not show potential for meeting the newly established detector performance. As a result, further development of these devices will not be made.

Airport Pavement Research

FAA is undertaking a project to develop a pavement maintenance management system (PMMS). The PMMS will be based on automated records of pavement conditions, maintenance frequency, and rehabilitation costs. Conditions and costs would be given a numerical rating and then stored in a microcomputer data file. The file and associated software will provide managers with timely information for selecting cost-effective maintenance and rehabilitation strategies and allow them to forecast future pavement conditions under a variety of budgetary levels. Such a program will optimize expenditures on either a network or project basis. It also will assist in setting project priorities and making realistic estimates of current and projected needs.

Assisted by the U.S. Army Cold Regions Research and Engineering Laboratory at Hanover, New Hampshire, FAA also studied the pavement problems caused by weather conditions in cold climates. The results of a previous study were used to modify pavement design to minimize frost heave and thaw, which weaken pavements. During 1984, the study sought to make modifications to asphalts, soils, and other pavement materials in order to improve their thermal stabilities. When the results of these studies are applied, pavements in cold regions are expected to improve on performance and serviceability.

Late in 1984, FAA began a project to determine the feasibility of developing soft-ground aircraft arresting systems. Such systems would be incorporated in the extended runway safety area. Studies will be made of various materials—sand, gravel, foam, and others—to determine their suitability as "soft ground" and the length of "soft ground" needed to decelerate an aircraft safely. If the soft concept proves feasible, FAA will issue a standard to aid airports in providing such a safety feature from the end of the runway pavement outward. The project had its genesis in a recommendation made to the FAA by the National Transportation Safety Board.

FAA also conducted research leading to the development of detailed standards for the new Precision Approach Path Indicator (PAPI), which was adopted by the International Civil Aviation Organization (ICAO) as the new world standard for approach lights, replacing the long-used Visual Approach Slope Indicator. In preparing for the issuance of specifications for the new system, FAA developed photometric parameters, including brightness, angular coverage, and transition zones. Developed in the United Kingdom, PAPI will be required at all U.S. airports that serve international flights.

In other runway-related developments, FAA conducted research on equipment that can be used in adverse weather to denote the holding position at intersections of taxiways and/or runways. Current markings on pavements at such intersections are difficult to see in fog or poor weather; hence, FAA will supplement current markings with an alternating light known as a "wig wag." This light also was developed in the United Kingdom and tested at London's Heathrow Airport. During 1984, FAA's research concentrated on determining the wig wag's optimum flash rate, brightness, light size, and positioning.

Aviation Weather

In July 1984, in the Denver-Stapleton Airport area, the FAA and the National Center for Atmospheric Research (NCAR) began an operational evaluation of wind shear forecast and detection system based on the forecast use of Doppler radar information in conjunction with other air mass data. During the evaluation, NCAR meteorologists issued a daily microburst forecast and kept FAA controllers up to date on actual and potential microburst activity within a five-mile radius of Stapleton Airport. A microburst is a violent downward rush of air associated with thunderstorms that flattens out when it hits the ground and spreads in all directions, creating wind shear conditions. Aircraft caught in these conditions first encounter a head wind that causes extra lift as it moves over the wings. This is suddenly replaced by a tail wind that produces a sharp loss of lift that can cause aircraft at low altitude to lose flying speed.

Doppler radar has proven effective in detecting microburst activity in research situations. Unlike conventional radar, it can "see" inside storms and measure changes in wind speed and direction. The Denver area was selected for the wind shear studies because of the high incidence there of microbursts.

Air Navigation and Air Traffic Control

National Airspace System Plan

FAA continued to strengthen its management structure to implement the massive, 450-page National Airspace System (NAS) Plan. First issued in December 1981 and updated each year at the request of Congress, the plan is a technological blueprint for modernizing FAA's air navigation and air traffic control system to meet the projected air traffic activity of the next two decades.

In January 1984, the NAS modernization program reached a significant milestone when FAA awarded the Martin Marietta Corporation a contract for systems engineering and integration support. As a function of this contract, Martin Marietta will share responsibility for assuring that the major components of the NAS Plan are properly designed, integrated, tested and installed and that they work as intended, in a timely and cost-effective manner. The contractor's specific tasks include:

- Verifying the soundness and feasibility of the plan and identifying areas for improvement.
- Performing independent verification and validation of the software produced for specific traffic control systems with significant software content, including the advanced automation system, which enables FAA to handle air traffic more expeditiously and at less cost than the current system.
- Providing program management support in areas such as cost, schedule, benefits, performance, planning, and configuration control.
- Providing FAA managers with technical support for some NAS Plan systems, reviewing the performance of and providing technical guidance to other system contractors, and assuring the proper integration and transition of these systems into the National Airspace System.
- Preparing a "blueprint" of the entire system, showing locations, performance requirements, and system linkages.

The contract runs for an initial period of five years, with options for three- and two-year extensions.

Earlier in 1984, another significant element of the NAS Plan was initiated when FAA awarded the Hazeltine Corporation a $90.6 million contract to begin equipping airports throughout the country with microwave landing systems (MLSs). These will replace the existing instrument landing systems (ILSs), which have been in use since the 1940s. The new landing system avoids some of the inherent technical problems of the ILS. The MLS signal, for example, is less vulnerable to environmental effects and less sensitive to structural or terrain influences. The new system also provides precision guidance with a flexibility that is not achievable with present ILS equipment, thus enhancing airport capabilities by offering pilots a broader range of approach paths to the runway. This will mean fewer flight delays, cancellations, or diversions because of bad weather. The contract called for Hazeltine to deliver 172 MLS units over a five-year period, beginning in 1985. The first units are expected to be installed in 1986 at airports in New England, Alaska, and Colorado. Current plans call for the installation of 1,250 units at U.S. airports by the year 2000.

Another major ground-to-air component of the NAS Plan is the Mode S radar beacon system, a new secondary radar system of advanced ground sensors and radar beacon transponders that will replace the existing air traffic control radar beacon system (ATCRBS). In October 1984, FAA awarded a $163.3 million contract to two corporations, Westinghouse and Burroughs, who are participating in a joint venture to produce 78 of the Mode S systems, with an option for 59 additional units. Unlike ATCRBS, which has no discrete address capability, Mode S will give controllers a "private line" to any airline cockpit in the air. The new radar beacon system thus will enable controllers to interrogate transponder-equipped aircraft individually and selectively to determine their position, identity, and altitude, without having to use voice communications. This eliminates overlapping and garbled signals that can be a problem in busy terminal areas. Delivery of the first ground station is expected in 1987.

In August 1984, FAA launched the competition for the Advanced Automation System by awarding two competitive design contracts, totaling nearly $247 million, to IBM and Hughes Aircraft. The contracts call for a three-year design competition to determine which company will produce the Advanced Automation System. Meanwhile, in July 1984, the competition for the host computer that will be used in the new system reached an important milestone. IBM and the Sperry Corporation, which had been awarded competitive design contracts in the fall of 1983, installed their computer systems for testing and evaluation at the FAA Technical Center. FAA is expected to select a winning host computer design in 1985.

Air Traffic Controller Selection

One of the most remarkable feats of large scale staffing for a highly technical occupation was the replacement by the Federal Aviation Administration and the Office of Personnel Mangement (OPM) of approximately 11,000 air traffic controllers following the August 1981 strike by the Professional Air Traffic Controllers Organization. The job was made easier by a new air traffic controller selection test battery, which had been developed by FAA. The battery is described in an FAA-sponsored book, published in 1984.

The controller test battery must be regarded as a major advance in the application of scientific, actuarial methods to the pre-employment selection of personnel for highly skilled technical specialties. Compared to the approaches that had become standard since World War II, the battery involves both innovation in test content and comprehensive concern with virtually every detail of a complex, sensitive area. The story of the development of this test is a research document of major importance and a valuable reference work for professionals and students in the field of personnel selection.

Almost simultaneously with the development of the new battery, FAA announced the National Airspace System Plan, which will gradually automate air traffic control. This meant that changes would be required in the selection program, perhaps within the next 10 years. The degree of change will depend on the rate at which new computers, radar, and communication systems come on line and preempt the customary functions of the controllers, and the extent to which the resulting changes would impose new requirements on those who perform the new functions. These issues are addressed in the final part of the book, which suggests new research and development to bring future selection procedures in line with requirements.

Office of Commercial Space Transportation

Under Executive Order 12465 and the Commercial Space Launch Act, the Department of Transportation (DOT) is the lead agency within the Federal government for encouraging, facilitating and coordinating the development of commercial expendable launch vehicle (ELV) operations by private United States enterprises. In carrying out these responsibilities, DOT reviews government policies affecting commercial ELVs, provides a single point of contract for the licensing of commercial ELV launches, and promotes and encourages commercial ELV operations in domestic and foreign markets.

A wide variety of firms responded to the Administration's initiative to encourage the private sector's participation in providing space transportation services on a commercial basis. While two new firms (Space Services, Inc. and Starstruck, Inc.) were pursuing space transportation activities on a commercial basis, companies like General Dynamics and Transpace Carriers, Inc. were approaching NASA about commercializing the Atlas Centaur and Delta rockets.

Secretary Dole established the Office of Commercial Space Transportation to act as the focal point for government and industry contacts regarding the initiative to promote and regulate commercial ELVs. A major emphasis is to streamline the regulatory requirements governing commercial space launch operations. To accomplish this, working relationships have been established with each of the government agencies that have major interests in space transportation and licensing.

Since the establishment of the Office of Commercial Space Transportation, a central licensing authority formerly under the International Traffic in Arms Regulations, has been transferred from the Department of State to the Department of Transportation. In October 1984, the Commercial Space Launch Act (PL 98-575) was enacted, confirming the DOT as lead agency and establishing the necessary statutory authority for the Department to carry out its licensing and promotional responsibilities.

Regulatory Activities

The Commercial Space Launch Act requires DOT to issue regulations implementing the provisions of the Act. The first of these regulations, a major regulatory policy statement, was completed in December 1984 and will be published for public comment in late January 1985.

In the near term, most commercial launch activity will occur on national (i.e., government-owned and operated) sites. Firms such as General Dynamics and Transpace Carriers, Inc. have vehicles that require the launch facility and resource support currently available only on national sites. In its first year, the Office of Commercial Space Transportation addressed the needs of both these large, established aerospace firms as well as smaller, emerging enterprises such as Space Services Inc. and Starstruck, Inc. In 1984, DOT licensed a test and demonstration launch, developed a new regulatory policy and licensing process for commercial launch sites, including requirements for safety and use, and established uniform guidelines for insurance requirements for private firms that conduct commercial launches.

As its first effort in connection with a specific launch proposal, DOT facilitated the Federal approval of a test launch conducted successfully by Startruck, Inc. off the coast of California on August 3, 1984. DOT staff worked with representatives of various approving agencies—the Departments of State and Defense, NASA, the Federal Aviation Administration, Materials Transportation Bureau, the U.S. Coast Guard, and others—to set licensing priorities, coordinate review activities, and expedite Federal approval. Additionally, DOT helped Starstruck to resolve problems at the State and local level. Once the license was issued, the Department of Transportation worked closely with other Federal agencies to identify acceptable offshore launch sites and to secure necessary clearances.

This experience helped DOT develop a streamlined licensing procedure to substantially simplify and shorten the Federal approval process by: (1) reducing or eliminating sequential coordination, (2) eliminating duplicative reviews through voluntary reliance of one agency upon another's work wherever possible, and (3) specifying each agency's information requirements in advance.

Under the Federal government's commercial space policy, the extensive resources and facilities at the national sites are to be made available to commercial launch firms. DOT has worked closely with private launch firms to encourage them to use the government's facilities, and assisted government launch site operators in their efforts to attract new developing launch companies as customers. In September, DOT acted as a "sponsor" for Space Services, Inc., formally introducing that firm to the national launch sites at Wallops Island and Vandenberg Air Force Base. DOT also is working with NASA and DoD to develop concepts and criteria for commercial ranges regarding launch site selection, site design, range and vehicle safety, flight safety corridors, and flight termination systems for commercially operated launch vehicles.

Liability insurance is a particularly important commercial space transportation issue because of the government's international obligations under existing outer space treaties. To establish a consistent government policy in this area, DOT and the Department of Justice, with cooperation from NASA and the Air Force, developed an arrangement to govern how future insurance requirements will be established for commercial launch operations.

Promotional Activities

DOT participated in two interagency policy groups, the Senior Interagency Group on Space and the Cabinet Council on Commerce and Trade, to draft a national space strategy and evaluate initiatives to promote and encourage private sector participation in commercial space endeavors.

DOT worked with other executive agencies to establish a pricing policy for the commercial use of national range facilities and services. Secretary of Defense Caspar Weinberger directed the DoD to promote the use of national launch sites within the private sector and to charge commercial users for the direct cost of services and facilities provided by the government. An additional set of waivers and other policy statements implementing this decision will be made public in January 1985.

During 1984, DOT worked with the Departments of State and Commerce, the Office of the U.S. Trade Representative (USTR) and NASA to develop policies to enhance the competitive posture of U.S. commercial ELVs in the world market. DOT representatives worked with the Commerce Department in preparing policy papers for spring 1984 meetings of the Organizaion for Economic Cooperation and Development (OECD). These efforts sought to establish an equitable and efficient international trading regime for space products and services.

DOT also is assisting USTR in an investigation and consultations relating to an alleged violation of section 301 of the 1974 Trade Act. Transpace Carriers, Inc., a new entrepreneurial launch firm that markets the Delta rocket, brought the initial complaint of unfair pricing practices, seeking fair and reasonable competitive market conditions. After an investigation by an interagency group, of which DOT is a member, the USTR will recommend to the President what action, if any, should be taken.

To institutionalize the flow of information between the private sector and the Federal Government, the Secretary of Transportation established the Commercial Space Transportation Advisory Committee to identify and eliminate barriers to ELV commercialization. The committee includes representatives of major aerospace manufacturers, large and small launch companies, satellite manufacturers, communications companies, investment firms, the space law community, insurance brokers and underwriters, the research and academic communities, and other experts in the space field. At its first meeting, held in October, the Committee made in eight recommendations which were forwarded to the Secretary for her consideration.

Environmental Protection Agency

The Environmental Protection Agency has cooperated with NASA in the development of various LIDAR (Light Detection and Ranging) laser systems for monitoring the environment, and in the analysis of observations of special regional scale atmospheric field studies. In a special application, the airborne UV-DIAL (Ultra-Violet - Differential Absorption LIDAR) system was deployed in the summer of 1981 to provide an observational basis for examining pollutant deposition above the mixing layer resulting from convective cloud activity. In 1984, analysis focused on the character of the cloud residue. The results supported an earlier hypothesis that convective clouds induce significant exchanges of pollution concentrations between the mixed and cloud layers. Moreover, the character of the cloud residue evolved into highly correlated layers of ozone and aerosols which elongate and tilt in the vertical as a result of mean wind shear.

The Environmental Protection Agency partially supported the development of the NASA UV-DIAL option (a working model that was flown in aircraft). The results, as noted above, were excellent. However, the NASA option, because of its size, requires a large aircraft. Consequently, there is a need to reduce its size for more cost effectiveness.

Toward this objective, recent advances in laser and electronic technology are being utilized to miniaturize the UV-DIAL system for subsequent use in a light twin engine (cost-effective) aircraft. In 1984, EPA was constructing such a device. Still in a laboratory testing phase, the miniaturized system will allow the simultaneous measurement of sulfur dioxide and ozone. Using its experience in laser technology (UV-DIAL in particular), NASA is aiding EPA in this project. NASA's assistance concentrates on advanced technologies for determining pollutant concentrations for LASER signal returns; correcting pollutant concentration values of interferences from other atmospheric pollutants; and for calibrations of the system. The Environmental Protection Agency system incorporates a RAMAN shifted eximer laser and multi-wavelength receiver - detector system. NASA is partially supporting the evaluation and testing of the EPA system in order to establish the utility of this instrument for potential use in its satellite/shuttle systems.

Future Activities

Remote sensing devices (like airborne and spaceborne LIDAR) will provide powerful, cost effective tools for analyzing the dynamics of pollutant transport and transformation phenomena. Expectations are that this approach will make it possible to distinguish between gases and aerosols in atmospheric concentrations of pollution and to trace in the air the transport path of each of the agents that are of concern. This knowledge can lead both to better understanding of pollutants and ultimately to their control.

National Science Foundation

The National Science Foundation (NSF) supports research in both astronomy and atmospheric science. In the first area, NSF's 1984 support for ground-based and theoretical astronomy came through five grant programs benefiting more than 140 universities, plus funding for 3 National Astronomy Centers.

In the atmospheric sciences, NSF provides the primary backing for research by universities and other groups (nonprofit and profit-making) in the United States. It also supports the National Center for Atmospheric Research (NCAR) and the Upper Atmospheric Facilities (UAF) program. NCAR, in Boulder, Colorado, conducts large scientific research programs that could not be done easily by a single university. The UAF supports four incoherent-scatter radar facilities in a chain stretching from Greenland through the United States and from Puerto Rico to Peru.

Astronomy

Far-reaching scientific advances made in 1984 in astronomy included significant achievements in high-resolution radio maps. These maps, made by the Very Large Array and other telescopes through the technique of very long baseline interferometry, display unprecedented detail in the cores of the Milky Way and other galaxies. The maps reveal surprising similarities in those cores, such as the probable presence of supermassive, gas-accreting black holes.

The use of sensitive electronic detectors and image-processing techniques such as speckle interferometry is being extended from the optical region to other regions of the spectrum. These include the infrared, where cool, low-mass stars were discovered as a result. Also, detailed analysis of starlight has confirmed the existence of solar-type phenomena such as spots on other stars.

Atmospheric Sciences

Atmospheric science combines knowledge of physics, chemistry, mathematics, and other sciences to improve our understanding of the earth's atmosphere—from the planet's surface to outer space. The Foundation aided basic atmospheric research on a wide range of subjects in 1984. It also continued as the chief supporter of academic research in the atmospheric sciences.

In 1984, atmospheric scientists emphasized these activities:

- Planning, observations, analyses, and expanded instrument development for atmospheric chemistry research and for mesoscale phenomena (those 10 to 100 kilometers in spatial extent).
- Climate studies on interaction between the atmosphere and the oceans, especially conditions in the Pacific that influence U.S. climate.
- Early development of a prototype, interactive, computing network to link universities to NCAR's data-bases and computing capabilities; acquisition of a mass storage system for NCAR's computing facility.
- Development and use of new instruments to measure vibrations on the sun's surface—with the goal of probing the sun's interior.
- Use of supercomputers for numerical simulation of space plasma phenomena that are responsible for solar-terrestrial interactions. This is a new development because of the availability of supercomputers now.
- University acquisition of computer hardware for networks that aid data exchange; remote use of computers; and computer code development.

Smithsonian Institution

National space goals are implemented and advanced by the Smithsonian Institution's programs of basic research at its Smithsonian Astrophysical Observatory (SAO) in Cambridge, Massachusetts, and through the exhibits, public programs, and educational activities of its National Air and Space Museum (NASM) in Washington, D.C. The NASM also conducts research in both planetary science and space history.

Space Sciences

High Energy Astrophysics

During 1984, the reduction and analysis of HEAO-1 and HEAO-2 satellite data continued. Observations made between 1978 and 1981 by the HEAO-2 or *Einstein* satellite still represent the most sensitive X-ray data available; and ongoing research programs involve all types of astronomical objects. New gains in science reported in 1984 included the determination of the onset of coronal activity in some stars, the discovery of a rapidly spinning Crab-like pulsar in the Large Magellanic Cloud, and the use of X-ray coronae to determine size and masses for halos around many galaxies.

Other research projects based on *Einstein* data ranged from studies of stellar x-ray emission to the source of the extra-galactic x-ray background. Investigations resulted in the discovery of two more compact objects in supernova remnants, the identification of the COS-B gamma-ray source GEMINGA with a probable neutron star, observations of scattering of x-rays from interstellar dust, the use of observations of clusters of galaxies to probe the intergalactic medium, and extension of the x-ray survey of quasars.

Approximately 70 Guest Investigators participated in the *Einstein* research program during 1984; and a data bank was established at SAO to allow full access to the *Einstein* data by the international scientific community.

Infrared Astronomy

A small, helium-cooled, infrared telescope (IRT), designed for the Spacelab 2 mission of the Space Shuttle, underwent functional and environmental testing at Marshall Space Flight Center and was delivered to Kennedy Space Center for integration tests preparatory to flight. The IRT will map the diffuse infrared flux from celestial sources and measure, as well, any Shuttle-induced contamination.

A 102-cm balloon-borne infrared telescope, used for photometry, spectroscopy, and high-resolution mapping of far-infrared celestial sources, was flown from the National Scientific Balloon Facility, Palestine, Texas, in April 1984. Nine hours of observations were obtained on more than seven molecular cloud complexes thought to be regions of star formation.

Geophysics

Research at NASM included the study of surface hydrology, soils, and soil erosion in the Inland Niger Delta of Mali, and the establishment of a program to study dune migration and soil erosion in other arid regions, using a variety of data provided by remote sensors on satellites such as Landsat. Among early results of the Niger Delta study are the development of preliminary fluvial system and soils maps. Intitial work in dune migration is focused on characterizing the spectral reflectance properties of the actively moving portions of the Abu Muharik dune system near El-Harra oasis in Egypt, using the Landsat's multispectral scanner (MSS) data. These results are being used to model the migration of longitudinal dunes.

Planetary Sciences

Data from the Voyager spacecraft contributed to a number of observational programs involving a variety of phenomena on Jupiter, Saturn, and the satellites of these planets. For example, rapid progressive waves in Jupiter's haze layer were seen in frames of the Jovian crescent; Enceladus was observed to be the source of Saturn's E rings; and asymmetry of Saturn's rings was seen at large phase angles and from the unilluminated side. A study of the morphology of the spokes on both faces of Saturn's B Ring was completed as well as a preliminary geological map of a section of the Jovian satellite Ganymede, using Voyager photographs.

In other programs using satellite data, a new model of the geomagnetic variation in the Earth's thermosphere and exosphere was completed and integrated into a comprehensive atmospheric model. Additionally, techniques were developed for the analysis of the Doppler tracking data from the Pioneer Venus Orbiter

(PVO) and its geophysical interpretation in conjunction with Venus topography derived from radar images.

Research on the structural evolution of the planets at NASM's Center for Earth and Planetary Studies concentrated on relating the locations and orientations of tectonic surface features, such as ridges, rilles, and lineaments, to presumed or known structural trends. These studies were applied to basins on Moon and Mercury as well as ridge orientations in the Tharsis region of Mars.

The dichotomy between the smooth plains of its northern hemisphere and the ancient, heavily cratered terrain of its southern hemisphere is a problem unique to Mars. The boundary between the two hemispheres is characterized by diverse geologic units and morphologic features, ranging from the outflow channels of Chryse Planitia to the small volcanic cones of Cydonia. Portions of this boundary may have formed originally as a scarp north of its present position, followed by southward migration through cliff retreat to the current location.

Department of State

International cooperation has been an important element of the United States' civil space program since the program's inception more than two decades ago. The United States derives important foreign relations benefits from this international effort, of which the Department of State is a vigorous proponent. An active program of international cooperation in the exploration of space as well as in space-related fields will continue to characterize the United States approach to the use and exploration of outer space.

An example of the U.S. commitment to international cooperation in space is the Manned Space Station Program announced by the President in his 1984 State of the Union Address. This major initiative inviting international participation in a large, long-term complex project will employ the latest developments in space technology. During 1984, the Department of State worked closely with NASA and other interested agencies to assure that this program will support and promote United States foreign policy interests. Our allies and other nations have welcomed the Space Station Program because it provides the opportunity for new cooperative arrangements in the space field and once again clearly puts the United States and the West in the forefront of space developments.

In addition to the opportunities for cooperation, the United States today faces the challenges of competition in space. Leadership in space remains a factor between the United States and the Soviet Union. While this aspect of East-West rivalry has diminished since the 1960's, it still catches the imagination of people around the world. NASA's Space Station Program should give a solid leadership advantage to the United States.

Recently, the United States has taken steps to enhance its international competitive position, among the most important of which must be counted commercial initiatives: the authorization and encouragement of commercial expendable launch vehicles and the expanded opportunities for commercial remote sensing applications anticipated in the transfer of the Landsat program to the private sector. A strong supporter of these steps, the Department of State, in coordination with other agencies, worked in 1984 to create an international environment in which United States commercial space activities can compete effectively.

The principal role of the Department of State in international civil space activities is to harmonize U.S. international objectives and interests, and to integrate those interests into our overall foreign policy objectives. Of special importance to the Department of State has been U.S. participation in multilateral institutions concerned with outer space issues. Foremost among these institutions has been the U.N. Committee on the Peaceful Uses of Outer Space—COPUOS.

Activities Within the United Nations

Outer Space Committee

The Committee on the Peaceful Uses of Outer Space (COPUOS) began its 1984 cycle of meetings with the annual session of the Scientific and Technical Sub-Committee in New York, February 13-24, 1984. At that time, the U.S. delegation reviewed unfortunate developments relating to COPUOS in the 38th Session of the U.N. General Assembly and delivered a statement noting that the Committee was embarked upon an agenda of confrontation and politicization, requiring the United States to consider its future relationship to the Committee. That statement also announced that the United States had decided for the foreseeable future to reduce considerably its involvement and support for various activities under the Committee's auspices, while expressing a willingness to work with all delegations interested in finding more constructive ways of doing business in the Committee, as well as what the Committee's proper business should be. Thus during 1984 the future relevancy of the 53-member Committee was threatened as a result of the wholesale break with the consensus procedure in the 38th Session of the U.N. General Assembly. Over the objection of the United States and other Western states, this break was used to place on the Committee's agenda "questions relating to militarization" as well as a mandate for its Legal Subcommittee to negotiate new legal principles to govern the geostationary satellite orbit. By the end of 1984, however, progress had been made in restoring the principle of consensus and a businesslike agenda in the Committee and its Sub-Committees.

For the remainder of 1984, U.S. delegations to COPUOS meetings continued to emphasize serious concerns with the course of the Committee, and to focus those concerns specifically on the following areas:

- restoration of the consensus principle;
- removal of the "militarization" item from the COPUOS agenda;

- removal of a negotiating mandate in the Legal Sub-Committee on the geostationary orbit item;
- re-invigoration of Committee's scientific and technical work; and
- examination of the Committee's work process and organization.

Most of these concerns also were emphasized by other Western delegations during the Scientific and Technical Sub-Committee session, the Legal Sub-Committee Session, March 19–April 6, 1984, in Geneva, and at the plenary meeting of COPUOS, June 11–22, 1984, in Vienna. To a large extent, Western concerns with the Committee dominated discussions in the Committee's sessions throughout 1984, with no substantive progress achieved on any agenda item. The June session of COPUOS also included the refusal of the United States delegation to participate in the debate scheduled on the "militarization" item.

U.N. General Assembly

By the time of the 39th Session of the UN General Assembly, the pressures for reform mounted by the United States and other Western states, began to produce some results. During the 39th session, the US Delegation delivered a detailed statement recounting the original objectives and terms of reference for the COPUOS, as proposed by the United States in 1958 and approved by the General Assembly at that time. The statement by the United States detailed the historical discussion underlying the General Assembly's original decision, when it established COPUOS, to separate the disarmament aspects of outer space from international cooperation in the peaceful uses of outer space.

Following a seven-week period of intensive negotiations in the Special Political Committee over a future agenda for COPUOS and its Sub-Committees, the General Assembly adopted resolution 39/96 by consensus. That resolution accommodated several important concerns of the United States, including the removal of militarization questions from the COPUOS agenda and the removal of a negotiating mandate in the Legal Sub-Committee regarding the geostationary satellite orbit. As a result of the return to consensus and the reformulation of the Committee's agenda, the United States expects to participate actively during 1985 in COPUOS and its Sub-Committees and will continue to work with other delegations to bring about constructive changes.

Communications Satellites

International Telecommunications Satellite Organization (INTELSAT)

The Board of Governors of INTELSAT approved the introduction of improved efficiencies in the organization by realignment of the executive organ, streamlining procedures for documentation, and transferring certain routine functions to the Director General. Many new services also were introduced in 1984. Provision of full and fractional transponder uses for digital TV distribution, integrated video and data, and international business leases were approved. A new micro-terminal service called INTELNET was approved in principle. It permits use of very small inexpensive antennas for very low speed data. New preemptible and non-preemptible leased international video services were agreed to and revisions were made for booking procedures to aid in advance planning for occasional use of television worldwide. INTELSAT has undertaken a review of its general charging policies in view of the introduction of so many new services.

At INTELSAT's annual meeting, its signatories expressed opposition to developments in the United States towards establishment of separate international satellite systems. The meeting adopted a resolution urging all signatories to refrain from entering into any arrangements which may lead to the establishment and subsequent use of these types of systems.

International Maritime Satellite Organization (INMARSAT)

INMARSAT has grown to 41 member countries representing more than 85 percent of the world's merchant shipping. About 2700 ships are outfitted with satellite terminals. In 1984, INMARSAT continued its leasing services through INTELSAT V satellites, a MARECS leased satellite from the European Space Agency and MARISAT satellites leased from COMSAT General, USA.

Our April 2, 1984, proposals for the second generation INMARSAT system were received from two international consortia, one led by British Aerospace with Hughes Aircraft and SATCOM International, the other led by Marconi with Ford Aerospace and Aerospatiale. The Director General has been authorized to conduct negotiations with both bidders to improve their basic offers and to provide conclusions and recommendations in early 1985.

In October 1984, Norway and the United Kingdom proposed amendments to the INMARSAT Convention and Operating Agreement to enable INMARSAT to provide aeronautical communications services. The proposals are generally consistent with the U.S. view that INMARSAT not be granted a monopoly in the provision of these services.

The organization continues to maintain a close working relationship with the International Maritime Organization, particularly in relation to development of the Future Global Maritime Distress and Safety System (FGMDSS).

Remote Sensing

The Department concluded its involvement in the Source Evaluation Board exercise to transfer the government Landsat earth remote sensing system program to commercial operation. In early June 1984, the Board made its recommendations to Secretary of Commerce Baldrige, who then assumed responsibility for final negotiations with the successful bidder. The Department also actively participated in the development of Public Law 98-365, the "Land Remote-Sensing Commercialization Act of 1984," signed into law July 17, 1984. The Department's interest was to assure an appropriate oversight role in any private commercial activities in land remote sensing by the United States that would have an effect on either foreign policy or bilateral or multilateral foreign relations.

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Arms Control and Disarmament Agency

An important part of the work of the United States Arms Control and Disarmament Agency (ACDA) is concerned with issues related to Outer Space arms control. ACDA also is involved in policy formulation for many U.S. activities in space.

On July 4, 1982, the President stated as National Space Policy that the United States will continue to study space arms control options and will consider verifiable and equitable arms control measures, compatible with U.S. national security, to ban or otherwise limit testing and deployment of specific weapon systems.

In a Report to the Congress on U.S. Policy on Anti-Satellite (ASAT) Arms Control on March 31, 1984, the President reaffirmed that policy and addressed as well potential benefits and problems of ASAT arms control and national security considerations regarding space.

Space Arms Control Activities

During 1984, the Agency participated in an intensive U.S. study of the options, benefits, and problems of space arms control, laying a sound foundation for any future negotiations.

On June 29, 1984, the Soviet Government announced that it had proposed to the United States that talks be held to "prevent the militarization of outer space." In its response accepting the Soviet proposal, the United States noted that "militarization of space began when the first ballistic missiles were tested," and added that, in addition, it would be prepared to discuss any other arms control concerns of mutual interest.

Subsequently, the Soviets changed their antisatellite testing moratorium "offer" to a precondition. In late July, to facilitate agreement on holding talks, the United States proposed a possible joint Soviet-American announcement on the content and objective of the talks, and included an explicit statement that the aim of the talks should be to work out and conclude agreements concerning the militarization of outer space, including antisatellite systems and other aspects of the issue. The Soviet Union did not accept the positive US response to their proposal and the Vienna talks were not held.

International Discussions on Space Arms Control

ACDA continues its efforts in support of U.S. space policy objectives in two multilateral arms control fora each year: the United Nations General Assembly (First Committee) and the Conference on Disarmament in Geneva. For several years, the basic issue in both bodies has been whether the United States will agree to a resolution or committee mandate calling for multilateral negotiation of a treaty or treaties limiting or banning certain activities in outer space. The position of the United States is that all aspects of arms control in outer space should be studied or debated, but that there has been insufficient analysis of the need for and verifiability of a major agreement for the control of weapons in outer space to justify acceding to multilateral negotiations.

Space Policy

ACDA is involved in all aspects of the formulation of US space policy. The Agency shares responsibility with the State Department for the interagency group which addresses space arms control issues and had a leading role in the intensive studies of potential ASAT arms control options and in the Administration's March 31, 1984, Report to the Congress on US Policy on ASAT Arms Control. ACDA also participated fully in the interagency effort to define the Strategic Defense Initiative (SDI) research program. Although not directly involved in the ongoing effort to determine the technical feasibility of eliminating the threat posed by strategic ballistic missiles, ACDA has a leading role in examining the arms control implications of the SDI.

In addition, the Agency participates in the work of the Senior Interagency Group on Space which considers a broad variety of space issues on which arms control considerations often are relevant, such as commercialization of expendable launch vehicles and the Presidentially mandated space station. Another Interagency Group in which ACDA is involved reviews the arms control implications of bilateral governmental space activities and sales of space-related items.

The United States remains committed to achieving effective arms control. In his remarks to the 39th Session of the United Nations General Assembly on September 24, 1984, President Reagan pledged to redouble "efforts to meet the legitimate expectations of all nations that the Soviet Union and the United States will substantially reduce their own nuclear arsenals" and emphasized U.S. interest in space arms control.

United States Information Agency

The public diplomacy efforts of the United States Information Agency (USIA) reflect its committment to the promotion of worldwide awareness of U.S. achievements in the exploration and peaceful uses of space. USIA has made effective use of direct satellite television and live radio braodcasts, on-the-spot news coverage, feature stories, interviews, exhibits, overseas visits by astronauts and scientists, and video tape programs for television. USIA maintained a focus on Space Shuttle Flights, stressing the increasingly international flavor of these missions and their growing commercial, as well as scientific value. Significant attention was also given to the initiative for an internaional effort to build a permanently manned space station.

Space Shuttle

Worldnet, USIA's interactive, state-of-the-art television network which links Washington via satellite with U.S. embassies and posts overseas, has received enthusiastic reaction to live press conferences with Shuttle astronauts in flight. "Astronet," the world's first extraterrestrial news conference, connected the Columbia astronauts orbiting the earth, President Reagan in Washington, and West German Chancellor Kohl in Athens, with over 70 European journalists in eight countries. President Reagan called the broadcast "one heck of a conference call." In October "Astronet II," telecast to posts in East Asia, featured live, two-way TV interviews by correspondents in Sydney with the seven member crew of the Space Shuttle Challenger. Media response to the program was extensive; USIS Canberra commented that the programs received the best TV coverage of any Agency production since "Let Poland be Poland."

USIA's television service also featured the October flight of the Challenger in a thirty minute VCR produced for window box displays at Eastern European posts. These displays proved highly popular with the East European public, so much so that USIS posts faced a variety of attempts to keep people away, disrupt the displays or block the film from public view. Other USIA television programs such as the monthly "Science World" series and the weekly "TV Satellite File" newsfeed featured scientific advances deriving from the Shuttle and highlighted key events such as the retrieval, repair and relaunch of the Solar Maximum Mission Satellite. Acquired films of Shuttle missions and press conferences with Shuttle crews were popular items for showing to audiences at USIS posts.

Lift-offs, flights and landings of each manned mission are covered at the scene by VOA News correspondents and frequently by reporters from key foreign language services. VOA's reporters have been at the Cape for space launches since Alan Shepard's flight. Today, VOA's on the scene coverage serves both tradition and program policy. VOA intends to continue fulfilling its listener's expectations for news of mission events—successful or unsuccessful—*as they occur.* In 1984, VOA news and foreign-language broadcasters covered the launches and landings of all seven Shuttle flights and key mission events such as the recovery of two satellites which had been placed in erratic and useless orbit. In a somewhat off-beat assist, VOA has loaned to a group of NASA staffers who have formed the Goddard Amateur Radio Club a cartridge machine which enables them to transmit shuttle communications with ground control for ham operators the world over.

Audience relations activities at VOA provided another avenue for communicating with listeners about America's exploration of space. One of the most frequent requests received from VOA listeners is for information on U.S. space exploration. Several brochures are available for responding to these requests. VOA's promotional activities include a postcard picturing a Challenger lift-off and several brief stories on space carried in the "Voice" magazine, which has a distribution of over 100,000. The 1984 VOA calendar "Dateline USA," which carried the theme "how VOA covers news events," featured on its cover a photo of Mission VI astronauts working in the open shuttle bay.

USIA's Press and Publications Service provided USIS posts and offices worldwide with numerous articles for background, post publications, and placement in the local media. Extensive coverage of Shuttle missions, scientific experiments, direct and spin-off benefits, and future goals was carried on the "Wireless File" to 214 posts in 134 nations and jurisdictions. Particular emphasis was given to items which would be of most interest to foreign audiences, such as the proposed development of a space station with international cooperation and plans to include more foreign astronauts on Shuttle flights. Several pamphlets related to space flight and international cooperation were also produced. The USIA magazines *Topic, America Illustrated,* and *Economic Impact* featured stories on the Shuttle and its economic and scientific benefits. In addition to two covers of *America Illustrated,* USIA's monthly Russian language magazine disributed in the Soviet Union under a reciprocal exchange agreement, *Topic* (distributed in Sub-Saharan Africa) and *Dialogue* also sported space related covers.

The American Participant program continued to arrange meetings of U.S. astronauts with foreign scientists, government officials, academics and journalists. Speaker programs featuring astronauts are highly popular and invariably generate extensive media coverage. In 1984, three astronauts visited a total of eleven countries. Astronaut Bruce McCandless spent most of May traveling to Nigeria, Zimbabwe, Zambia, Tanzania, Saudi Arabia, and Spain. Also in May, Dr. Ronald McNair visited Hong Kong, Thailand, India and Bahrain. The dedication of a "space house" in Kiruna, Sweden, north of the Arctic circle was a highlight of Astronaut Karol Bobko's September visit to Sweden.

Telepress conferences, a telephone hookup of spokemen in the U.S. with foreign newsmen abroad, provided another effective means to bring astronauts and foreign audiences together. In March, reporters in Guatemala City interviewed Bruce McCandless about the success of the backpack in untethered spacewalks. In July, Kathryn Sullivan discussed the U.S. Space Program with media in Abidjan.

In Washington, the Foreign Press Center held a briefing for foreign media by NASA Administrator James Beggs, discussing space station plans. The Foreign Press Center also provided facilitative assistance to journalists from nine countries whose requests included information on future shuttle flights, interviews with spokesmen or astronauts, tours of NASA facilities, and even one request for information on if and when journalists may go on a fûture space mission.

Other Programs

The scientific/technical side of USIA's relationship with NASA is another significant link between the two agencies. In a continuing effort, VOA and NASA are jointly pursuing studies to determine the technical feasibility and cost effectiveness of Direct Broadcast Satellite systems. Similarly, advanced satellite communications were central to "Videcon '84," a five day joint USIA-COMSAT experimental demonstration of live, two-way, compressed, digital, video transmissions between USIA studios in Washington and BTI studios in London. Advances in space science and technology were highlighted in numerous Wireless File and magazine articles and TV productions such as "Science World."

In cooperation with USIA's Exhibits Service, Astronaut Norman E. Thagard visited the U.S. exhibit at the Pacific National Exhibition held in August in Vancouver. He acted as grand marshall for the opening day parade and participated in the official opening day ceremonies. This annual exhibition draws approximately one million persons from Canada and the U.S. In October, NASA provided three exhibits which were displayed at the annual International Salon of Food and Agriculture in Montreal. This event, important to the Quebec agri-food sector, promotes all activities related to the production, processing and marketing of agricultural and food products.

USIA's Exhibits Service is organizing the official U.S. participation in World's Fairs scheduled for 1985 and 1986. Preparations are underway for the U.S. national exhibition of Expo '85 in Tsukuba, Japan, which will include displays of the Martin Marietta Manned Maneuvering Unit, a Space Shuttle suit and a 1:30 scale model of McDonnell Douglas's proposed Space Station. In keeping with efforts to promote international cooperation in space, the major theme of the U.S. exhibition at Expo '86 in Vancouver, Canada will be space exploration, with the U.S. pavilion featuring the proposed space station.

Appendixes

APPENDIX A-1

U.S. Spacecraft Record

(Includes spacecraft from cooperating countries launched by U.S. launch vehicles.)

Calendar Year	Earth Orbit[a]		Earth Escape[a]	
	Success	Failure	Success	Failure
1957	0	1	0	0
1958	5	8	0	4
1959	9	9	1	2
1960	16	12	1	2
1961	35	12	0	2
1962	55	12	4	1
1963	62	11	0	0
1964	69	8	4	0
1965	93	7	4	1
1966	94	12	7	1[b]
1967	78	4	10	0
1968	61	15	3	0
1969	58	1	8	1
1970	36	1	3	0
1971	45	2	8	1

Calendar Year	Earth Orbit[a]		Earth Escape[a]	
	Success	Failure	Success	Failure
1972	33	2	8	0
1973	23	2	3	0
1974	27	2	1	0
1975	30	4	4	0
1976	33	0	1	0
1977	27	2	2	0
1978	34	2	7	0
1979	18	0	0	0
1980	16	4	0	0
1981	20	1	0	0
1982	21	0	0	0
1983	31	0	0	0
1984	35	3	0	0
Total	1,064	137	79	15

[a] The criterion of success or failure used is attainment of earth orbit or earth escape rather than judgment of mission success. "Escape" flights include all that were intended to go to at least an altitude equal to lunar distance from the earth.

[b] This earth-escape failure did attain earth orbit and therefore is included in the earth-orbit success totals.

APPENDIX A-2

World Record of Space Launchings Successful in Attaining Earth Orbit or Beyond

(Enumerates launchings rather than spacecraft; some launches orbited multiple spacecraft.)

Calendar Year	United States	U.S.S.R.	France	Italy	Japan	People's Republic of China	Australia	United Kingdom	European Space Agency	India
1957		2								
1958	5	1								
1959	10	3								
1960	16	3								
1961	29	6								
1962	52	20								
1963	38	17								
1964	57	30								
1965	63	48	1							
1966	73	44	1							
1967	57	66	2	1			1			
1968	45	74								
1969	40	70								
1970	28	81	2	1[a]	1	1				
1971	30	83	1	2[a]	2	1		1		
1972	30	74		1	1					
1973	23	86								
1974	22	81		2[a]	1					
1975	27	89	3	1	2	3				
1976	26	99			1	2				
1977	24	98			2					
1978	32	88			3	1				
1979	16	87			2				1	
1980	13	89			2					1
1981	18	98			3	1			2	1
1982	18	101			1	1				
1983	22	98			3	1			2	1
1984	22	97			3	3			4	
Total	836	1,733	10	8	27	14	1	1	9	3

[a] Includes foreign launchings of U.S. spacecraft.

Successful U.S. Launches—1984

Launch Date (GMT), Spacecraft Name, COSPAR Designation, Launch Vehicle	Mission Objectives, Spacecraft Data	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
Jan. 31 Defense 9A Titan 34D	Objective: development of spaceflight techniques and technology. Spacecraft: Not announced.	Not available	Still in orbit.
Feb. 3 Space Shuttle Challenger (STS-41B) 11A	Objectives: To deploy Westar-6 and Palapa-B2; rendezvous test operations using Integrated Rendezvous Target (IRT); testing and evaluation of Manned maneuvering Unit (MMU). Spacecraft: Shuttle carrying two communications satellites, balloon rendezvous target, Cinema 360, 5 get-away specials (GASs), Acoustic Containerless Experiment System (ACES), Isoelectric Focusing (IEF), Monodisperse Latex Reactor (MLR), 1 student experiment, Shuttle Pallet Satellite (SPAS-01A). Total payload weight (including 1,814 kg for crew equipment): 37,358 kg.	297 278 90.3 28.5	Fourth flight of Orbiter Challenger piloted by astronauts Vance D. Brand and Robert L. Gibson. Mission specialists were Bruce McCandless, Ronald E. McNair and Robert L. Stewart. Shuttle liftoff from KSC at 8:00 a.m. EST. Satellites were deployed from cargo bay. PAM-D on both communications satellites failed, leaving satellites in low orbit. First use of MMU in space. Challenger landed on KSC runway 15 at 7:16 a.m., EST, Feb. 11. Total mission time: 7 days, 23 hours, 16 min.
Feb. 3 Westar-6 11B	Objective: To launch Westar-6 satellite to stationary geosynchronous orbit with sufficient stationkeeping propulsion fuel on board to meet support requirements and to initiate user support services. Spacecraft: Drum-shaped telescoping cylinder 6.8 m high when deployed in space; 2.16 m in diameter; spin stabilized. Carries 24 color TV channels. Weight in orbit after apogee motor fire: 1099 kg.	1220 307 100.1 27.7	Launched Feb. 3 from Shuttle orbiter Challenger, PAM-D failure in low orbit. Satellite retrieved by orbiter Discovery (STS-51A) Nov. 14, returned to earth Nov. 16 for refurbishment.
Feb. 5 IRT 11C	Objective: To deploy balloon and perform rendezvous using balloon as passive target. Spacecraft: Balloon, 2 m in diameter, inflated automatically with nitrogen to pressure of .3 psia.	267 261 89.8 28.5	Launched Feb. 5 from Shuttle orbiter Challenger, failed to inflate. Rendezvous Radar work successfully done using deflated target.
Feb. 5 Defense 12A Atlas H	Objective: Development of spacecraft techniques and technology. Spacecraft: Not announced.	Not available	Still in orbit.
Feb. 6 Palapa-B2 11D	Objective: To launch satellite into transfer orbit of sufficient accuracy to permit spacecraft to achieve geosynchronous orbit for communications. Spacecraft: drum-shaped, identical to Westar-6. Weight in orbit after reaching geosynchronous orbit: 630 kg.	1190 280 99.5 28.2	Launched Feb. 6 from Shuttle Challenger for Republic of Indonesia. PAM-D failure in low orbit. Satellite retrieved by orbiter Discovery (STS-51A) Nov. 12, returned to earth Nov. 16 for refurbishment.
March 1 Landsat-5 21A Delta 3920	Objective: To launch spacecraft into circular, near polar Sun-synchronous orbit of sufficient accuracy to allow imaging the same 185 km swath of earth's surface every 16 days. Spacecraft: Main spacecraft body consists of multimission modular spacecraft (MMS) and instrument module (IM); high-gain antenna mounted at end of 4 m mast for Tracking and Data Relay Satellite System (TRDSS) communications, single-wing solar array. Principle instruments are thematic mapper (TM) and multispectral scanner (MSS), both in instrument module. Weight: 1947 kg.	700 699 98.8 98.2	Launched by NASA into circular, near-polar Sun-synchronous orbit, replacing ailing Landsat-4 launched July 16, 1982. MSS and TM providing excellent imagery.

APPENDIX A-3—Continued

Successful U.S. Launches—1984

Launch Date (GMT), Spacecraft Name, COSPAR Designation, Launch Vehicle	Mission Objectives, Spacecraft Data	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
Uosat-2 21B	Objective: To launch satellite for amateur radio communication relay. Spacecraft: Rectangular shape, 355 mm square and 645 mm high. Weight: 60.5 kg.	694 673 98.4 98.2	Secondary payload to Landsat-5 for University of Surrey (United Kingdom). Satellite sponsored by the Radio Amateuir Satellite Corporation (AMSAT).
April 6 Space Shuttle Challenger (STS-41C) 34A	Objective: To deploy the Long Duration Exposure Facility (LDEF) and repair the Solar Maximum Mission (SMM) satellite. Spacecraft: Shuttle carrying satellite with accommodations for experiments requiring long-term exposure to space. Cinema 360, IMAX, Radiation Monitoring Equipment (RME) and 1 student experiment. Crew and equipment weight: 1675 kg. Payload weight: 14,687 kg.	464 218 91.4 28.5	Eleventh flight of Space Transportation System. Orbiter Challenger piloted by Robert L. Crippen and Frances R. Scobee. Mission specialists Terry J. Hart, George D. Nelson and James D. Van Hoften. Shuttle lifted off from KSC at 8:58 a.m., EST. LDEF-1 successfully deployed from cargo bay. Solar Maximum Mission (SMM) satellite retrieved and repaired in cargo bay, redeployed April 12. Challenger landed on runway 17 at Edwards AFB, CA, 8:39 a.m., EST, April 13. Total mission time: 6 days, 23 hrs, 41 min. Orbiter returned to KSC for overhaul for next flight.
Long Duration Exposure Facility (LDEF-1) 34B	Objective: To place scientific, applications and technology experiments into earth orbit for substantial period of time. Spacecraft: 12 sided, open-grid structure, 9.14 m long, 4.27 m in diameter, passively stabilized. Weight: 9670 kg.	483 473 94.2 28.5	Successfully deployed, satellite originally scheduled for retrieval about 10 months after launch, but due to shuttle scheduling changes capture delayed.
April 14 Defense 37A Titan 34D	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	Not available	Still in orbit.
April 17 Defense 39A Titan IIIB	Objective: Development of spacecraft techniques and technology. Spacecraft: Not announced.	Not available	Reentered Aug. 13.
June 9 Intelsat V F-9 57A Atlas-Centaur	Objective: To place spacecraft in geosynchronous orbit for INTELSAT to provide 12,000 voice circuits and 2 color TV channels simultaneously. Spacecraft: Three axis stabilized, 6.4 m high and 15.9 m across extended solar panels. Weight at launch: 2,016 kg.	1220 233 99.3 28.7	Seventh of series of 9 satellite, launched by NASA for 108-member nation International Telecommunications Satellite Organization (INTELSAT). Launch vehicle failed to boost satellite to useful orbit. Reentered Oct. 25
June 13 Navstar-9 59A Atlas E	Objective: To launch satellite into planned orbit. Spacecraft: Same basic configuration as Navstar-8, launched in 1983. Weight: 873 kg.	20,619 20,317 729.6 62.5	Global Positioning System satellite launched by DoD in joint military services' developmental network. Still in orbit.
June 25 Defense 65A Titan 34D	Objective: Development of spacecraft techniques and technology. Spacecraft: Not announced.	230 170 88.9 96.1	Reentered Oct. 18.

Appendix A-3—**Continued**

Successful U.S. Launches—1984

Launch Date (GMT), Spacecraft Name, COSPAR Designation, Launch Vehicle	Mission Objectives, Spacecraft Data	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
Aug. 16 Charge Composition Explorer (CCE) 88A Delta 3924	Objective: To place satellite in near-equatorial elliptical orbit to detect ions within earth's magnetosphere. Spacecraft: Structure is a closed right octogonal prism. Weight in orbit: 242 kg.	49,663 1,130 939.5 5.1	One of 3 satellites comprising Active Magnetospheric Particle Tracer Explorers (AMPTE) Mission. Satellite contains 5 instruments: Hot Plasma Composition Measurement Spectrometer (HPC), Charge Energy Mass Spectrometer (CHEM), Medium Energy Particle Analyzer (MEPA), Magnetometer (MAG) and Plasma Wave Experiment (PWE). Data being returned. Still in orbit.
Ion Release Module (IRM) 88B	Objective: To place satellite in highly elliptical orbit for study of earth's magnetosphere. Spacecraft: 16 chemical release containers (8 barrium and 8 lithium). Weight: 705 kg.	113,741 553 2655.7 28.7	Second of 3 AMPTE satellites. Built by the Federal Republic of Germany. Results of chemical releases being analyzed.
United Kingdom Satellite (UKS) 88C	Objective: To observe barrium and lithium released by IRM. Spacecraft: Cylindrical satellite, 1 m in diameter and 0.45 m in height, spin-stabilized. Weight: 77 kg.	113,741 553 2655.7 28.7	Third of 3 AMPTE satellites. Built in the United Kingdom. Spacecraft operated in close proximity to IRM when barrium or lithium released. Results obtained. Satellite failed in orbit, January 1985.
Aug. 28 Defense 91A Titan IIIB	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	38,156 287 702.8 63.6	Still in orbit.
Aug. 30 Space Shuttle Discovery (STS-41D) 93A	Objective: To check out Space Shuttle, launch Syncom IV-2, Telstar-3C, and SBS-4; complete assigned experiments and test objectives. Spacecraft: Shuttle orbiter carrying satellites Syncom IV-2, Telstar-3C, SBB-4 and scientific payloads, OAST-1, Continuous Flow Electrophoresis System (CFES), IMAX, Radiation Monitoring Equipment (RME), Clouds Photograph Experiment and 1 student experiment. Total payload weight (including 1,799 kg for crew and crew equipment): 23,631 kg.	296 296 90 29.45	Twelfth flight of Space Transportation System, first flight of orbiter Discovery. Piloted by Henry W. Hartsfield, Michael L. Coats. Mission specialists: Richard M. Mullane, Steven A. Hawley, Judith A. Resnik. Payload specialist: Charles D. Walker. Shuttle launched from KSC at 8:42 a.m., EDT. Deployed three communications satellites, carried out experiments, including OAST-1 solar array structural testing. Discovery landed on runway 17 at Edwards AFB, CA, 9:38 a.m., EDT. Total mission time 6 days, 56 min. Orbiter returned to KSC for overhaul for next flight.
SBS-4 93B	Objective: To launch satellite into transfer orbit permitting spacecraft propulsion system to place it in stationary synchronous orbit for communications coverage. Spacecraft: Cylindrical, spin-stabilized. Weight: 3,344 kg.	35,796 35,777 1,436.1 0.3	Launched Aug. 31 from orbiter Discovery for Satellite Business Systems, Inc. In orbit.
Syncom IV-2 (Leasat-2) 93C	Objective: To launch satellite into successful transfer orbit. Spacecraft: Cylindrical, telescoping satellite. Weight: 6,889 kg.	35,798 35,776 1,436.1 3.2	Successfully deployed Aug. 31 from Discovery for Hughes Communication Service, Inc. for lease to the US Navy. Still in orbit.

APPENDIX A-3—Continued

Successful U.S. Launches—1984

Launch Date (GMT), Spacecraft Name, COSPAR Designation, Launch Vehicle	Mission Objectives, Spacecraft Data	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
Telstar 3-C 93D	Objective: To launch satellite into transfer orbit. Spacecraft: Cylindrical, spin-stabilized. Weight: 3,402 kg.	35,790 35,785 1,436.1 0.0	Deployed successfully from Discovery Sept. 1, for American Telephone and Telegraph Company. Still in orbit.
Sept. 8 Navstar-10 97A Atlas E	Objective: To launch satellite into planned orbit. Spacecraft: Same basic configuration as Navstar-9, launched June 13. Weight: 873 kg.	20,410 19,954 718.0 63.3	Still in orbit.
Sept. 21 Galaxy-3 101A Delta 3920	Objective: To launch spacecraft with sufficient accuracy to allow propulsion system to place satellite in stationary geosynchronous orbit. Spacecraft: Cylindrical telescoping design. 277 cm high and 216 cm in launch configuration. In orbit aft solar panel deploys, antenna reflector erects, 683 cm high. Weight: 519 kg.	35,795 35,783 1,436.2 0.0	Third in a series of three successfully launched by NASA for Hughes Communications. Inc. Positioned above equator at 93.5° west longitude.
Oct. 5 Space Shuttle Challenger (STS-41G) 108A	Objective: To launch Earth Radiation Budget Satellite (ERBS), perform scientific experiments using OSTA-3 and other payloads. Spacecraft: Shuttle orbiter carrying OSTA-3 payload: Shuttle Imaging Radar-B (SIR-B), Large Format Camera (LFC), Measurement of Atmospheric Pollution from Satellites (MAPS) and Feature Identification and Location Experiment (FILE); IMAX, Orbital Refueling System (ORS), Canadian Experiment (CANEX), Radiation Monitoring Equipment (RME), Thermoluminescent Dosimeter (TLD), and Auroral Photography Experiment (APE). 8 Getaway Special (GAS) experiments in cargo bay. Weight (including ERBS, not crew): 8,203 kg.	225 216 88.9 57.0	Thirteenth flight of Space Transportation System. Orbiter Challenger piloted by astronauts Robert L. Crippen, Jon A. McBride. Mission specialists: Kathryn D. Sullivan, Sally K. Ride and David C. Leestma. Payload specialists: Paul D. Scully-Power and Marc Garneau (Canadian). Challenger lifted off from KSC at 7:03 a.m., EDT, and landed at KSC, at 12:27 p.m., EDT. Total mission time: 8 days, 5 hrs, 24 min. Spacecraft returned to KSC for refurbishment and overhaul for next flight.
Oct. 5 Earth Radiation Budget Satellite (ERBS) 108B	Objective: To launch satellite enabling it to provide global measurements of the Sun's radiation reflected and absorbed by earth. Spacecraft: 4.6 m wide, 3.8 m high and 1.6 m long, three-axis momentum biased. Instrumentation: ERBE Non-Scanner (ERBE-NS), ERBE Scanner (ERBE-S) and Stratospheric Aerosol and Gas Experiment (SAGE II). Weight: 2,250 kg.	608 598 96.8 57.0	Successfully deployed by Challenger using Remote Manipulator System (RMS). ERBS one of three satellites in Earth Radiation Budget Experiment Research Program. NOAA-9 launched Dec. 12 and NOAA-G to be launched in late 1985. Instruments returning data.
Oct. 12 Nova-3 110A Scout	Objective: To launch Navy navigational satellite. Spacecraft: Same configuration of Nova-1 launched May 15, 1981.	1,198 1,152 108.9 90.1	Second in series of improved TRANSIT satellites launched by NASA. Still in orbit.
Nov. 8 Space Shuttle Discovery (STS-51A) 113A	Objective: To launch Anik-D2 and Syncom IV-1 and retrieve and return Palapa-B2 and Westar-6. Spacecraft: Shuttle orbiter carrying satellites Anik D2 and Syncom IV-1, as well as experiments Diffusive Mixing of Organic Solutions (DMOS) and Radiation Monitoring Equipment (RME). Total payload weight: 17,375 kg.	299 288 90.4 28.5	Fourteenth flight of Space Transportation System, second mission of orbiter Discovery piloted by Frederick H. Hauck and David M. Walker. Mission specialists Joseph P. Allen, Anna L. Fisher and Dale A. Gardner. Palapa-B2 retrieved Nov. 12, and Westar-6 secured in cargo bay Nov. 14. Discovery launched from KSC at 7:15 a.m., EST and landed at KSC, runway 15 7:00 a.m., EST , Nov. 16. Total mission time: 7 days, 23 hrs, 45 min.

APPENDIX A-3—Continued

Successful U.S. Launches—1984

Launch Date (GMT), Spacecraft Name, COSPAR Designation, Launch Vehicle	Mission Objectives, Spacecraft Data	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
Anik-D2 113B	Objective: To launch satellite into transfer orbit of sufficient accuracy to permit spacecraft to achieve geosynchronous orbit for communications. Spacecraft: Cylindrical 2.2 m diameter, 2.8 m high, in orbit deploys to height of 6.6 m, spin-stabilized. Weight: 730 kg.	35,800 35,772 1,436.0 1.8	Successfully launched Nov. 9, by Discovery for Telsat Canada; positioned over equator at 111.5° west longitude due south of Salt Lake City, UT. Still in orbit.
Syncom IV-1 113C	Objective: To launch satellite into transfer orbit permitting spacecraft propulsion system to place it in stationary synchronous orbit for communications coverage.	35,847 35,727 1,436.2 3.4	Launched Nov. 10, from Shuttle Discovery, second of four satellites to be leased by the DoD to replace FleetSatCom spacecraft for worldwide UHF communications between ships, planes, and fixed facilities. Still in orbit.
Nov. 14 NATO IIID 115A Delta 3914	Objective: To launch satellite into a synchronous transfer orbit of sufficient accuracy to allow the spacecraft propulsion system to place the spacecraft into a stationary synchronous orbit. Spacecraft: Drum-shaped, 2.18 m in diameter, 2.23 m long, with overall length of 3.1 m including antennas. Spin-stabilized. Designed lifetime: 7 years. Weight at launch 761 kg, after firing of apogee kick motor, 388 kg.	35,612 35,571 1,426.2 5.9	NASA successfully launched fourth in series of NATO defense-related communications satellites, on reimbursable cost basis. Satellite placed at 50° west longitude above the equator over the Atlantic Ocean. Still in orbit.
Dec. 4 Defense 122A Titan IIID	Objective: Development of spacecraft techniques and technology. Spacecraft: Not announced.	Not available	Still in orbit.
Dec. 12 NOAA-9 123A Atlas E	Objective: To launch spacecraft into Sun-synchronous orbit, conduct in-orbit evaluation and checkout of spacecraft. Spacecraft: "stretched" version of Tiros-N series, launch configuration 491 cm high, 188 cm in diameter. Solar array deploys in orbit. Weight: 1,712 kg.	862 841 102.0 98.9	Fifth NOAA-funded operational spacecraft of Tiros-N series, successfully launched by NASA, satellite replaced NOAA-7 as afternoon satellite in NOAA's two polar satellite system. Also onboard second set of Earth Radiation Budget Experiment (ERBE) instruments, Solar Backscatter Ultraviolet Spectral Radiometer, Mod-2 (SBUV/2) and Search and Rescue instruments. Spacecraft returning data. Still in orbit.
Dec. 22 Defense 129A Titan 34D	Objective: Development of spacecraft techniques and technology. Spacecraft: Not announced.	Not available	Still in orbit.

APPENDIX B-1

U.S.-Launched Applications Satellites 1978-1984

Date	Name	Launch Vehicle	Remarks
COMMUNICATIONS			
Jan. 7, 1978	Intelsat IVA F-3	Atlas-Centaur	Positioned over Indian Ocean.
Feb. 9, 1978	Fltsatcom 1	Atlas-Centaur	First of new Defense series.
Mar. 5, 1978	Oscar 8	Thor-Delta (TAT)	Secondary payload with Landsat 3, replacement for Oscar 6 for amateur radio communications.
Mar. 31, 1978	Intelsat IVA F-6	Atlas-Centaur	Positioned over Indian Ocean.
Apr. 7, 1978	BSE (Yuri)	Thor-Delta (TAT)	Japanese experimental direct-broadcast satellite for television; domestic satellite.
May 11, 1978	OTS 2	Thor-Delta (TAT)	European Space Agency experimental relay satellite; domestic satellite.
June 29, 1978	Comstar D-3	Atlas-Centaur	Positioned south of U.S. over the equator by Comsat; domestic satellite.
Nov. 19, 1978	NATO IIIC	Thor-Delta (TAT)	Final one of this military series.
Dec. 14, 1978	DSCS II-11,12	Titan IIIC	Defense communications (dual launch).
Dec. 16, 1978	Anik 4 (Telesat D)	Thor-Delta (TAT)	Launched for Canada; domestic satellite.
May 4, 1979	Fltsatcom 2	Atlas-Centaur	Second of new DoD series.
Aug. 9, 1979	Westar 3	Thor-Delta (TAT)	Launched for Western Union Co. as part of its domestic communications links.
Nov. 21, 1979	DSCS II-13,14	Titan IIIC	Defense communications (dual launch).
Dec. 2, 1979	RCA-Satcom 3	Thor-Delta (TAT)	Launched for RCA, but contact lost during orbit circularization.
Jan. 18, 1980	Fltsatcom 3	Atlas-Centaur	Third of DoD series.
Oct. 31, 1980	Fltsatcom 4	Atlas-Centaur	Fourth of DoD series.
Nov. 15, 1980	SBS 1	Thor-Delta (TAT)	Launched for Satellite Business Systems as part of its domestic communications links.
Dec. 6, 1980	Intelsat V F-2	Atlas-Centaur	First of new series, positioned over Atlantic.
Feb. 21, 1981	Comstar D-4	Atlas-Centaur	Fourth in series for Comsat General Corp.
May 23, 1981	Intelsat V F-1	Atlas-Centaur	Second in series for INTELSAT, positioned over Atlantic.
Aug. 6, 1981	Fltsatcom 5	Atlas-Centaur	Fifth in DoD series.
Sept. 24, 1981	SBS 2	Thor-Delta (TAT)	Second in series for Satellite Business Systems.
Nov. 20, 1981	RCA-Satcom 3-R	Thor-Delta (TAT)	Fourth in series for RCA, replacement for RCA-Satcom 3.
Dec. 15, 1981	Intelsat V F-3	Atlas-Centaur	Third in series. To be positioned over Atlantic.
Jan. 16, 1982	RCA-Satcom 4	Thor-Delta (TAT)	Fifth in series for RCA.
Feb. 26, 1982	Westar 4	Thor-Delta (TAT)	First in a series of second-generation for Western Union Co.
Mar. 5, 1982	Intelsat V F-4	Atlas-Centaur	Fourth in series; positioned over Pacific.
Apr. 10, 1982	Insat 1A	Thor-Delta (TAT)	First in series for India Department of Space.
June 9, 1982	Westar 5	Thor-Delta (TAT)	Second in series of second-generation for Western Union Co.; replaces Westar 2.
Aug. 26, 1982	Anik D-1	Thor-Delta (TAT)	Launched for Telesat Canada as replacement for in-orbit satellites.
Sept. 28, 1982	Intelsat V F-5	Atlas-Centaur	Fifth in series; positioned over Indian Ocean.
Oct. 27, 1982	RCA-Satcom 5	Thor-Delta (TAT)	Joined 4 operational satellites launched for RCA.
Oct. 30, 1982	DSCS II, DSCS III	Titan III(34) D/IUS	Defense communications (dual launch), including first in series of uprated satellites.
Nov. 11, 1982	SBS 3	Space Shuttle, PAM-D	Third in series for Satellite Business Systems.
Nov. 12, 1982	Anik C-3	Space Shuttle, PAM-D	Second in new series for Telesat Canada.
Apr. 4, 1983	TDRS 1	Space Shuttle, IUS	First in series. System to provide continuous satellite communication. Leased by NASA from Space Communications Co. (Spacecom).
Apr. 11, 1983	RCA-Satcom 6	Delta 3924	Replacement for RCA-Satcom 1, launched for RCA.
May 19, 1983	Intelsat V F-6	Atlas-Centaur	Sixth in series; positioned over Atlantic Ocean.
June 18, 1983	Anik C-2	Space Shuttle, PAM-D	Launched for Telesat Canada.
June 19, 1983	Palapa B-1	Space Shuttle, PAM-D	Indonesian domestic communications.
June 28, 1983	Galaxy 1	Delta 3920/PAM-D	Launched for Hughes Communications, Inc.
July 28, 1983	Telstar 3A	Delta 3920/PAM-D	Launched for American Telephone and Telegraph Co.
Aug. 31, 1983	Insat 1-B	Space Shuttle, PAM-D	Indian domestic communications.
Sept. 8, 1983	RCA-Satcom 7	Delta 3924	Replacement for RCA-Satcom 2, launched for RCA.
Sep. 22 1983	Galaxy 2	Delta 3920/PAM-D	Second in series, launched for Hughes Communications, Inc.
Feb. 3, 1984	Westar-6	Space Shuttle, PAM-D	Launched for Western Union, PAM-D failed to fire properly, satellite retrieved by Shuttle, and returned to earth for refurbishment.
Feb. 6, 1984	Palapa-B2	Space Shuttle, PAM-D	Launched for Indonesia, booster motor failed, satellite retrieved and returned to earth by Shuttle.

Appendix B-1—Continued

U.S.-Launched Applications Satellites 1978–1984

Date	Name	Launch Vehicle	Remarks
Mar. 1, 1984	Uosat-2	Delta 3920	Secondary payload with Landsat-5, for amateur radio communications.
June 9, 1984	Intelsat V F-9	Atlas-Centaur	Seventh in series, launch vehicle failure, satellite reentered Oct. 24.
Aug. 31, 1984	SBS-4	Space Shuttle, PAM-D	Launched for Satellite Business Systems, Inc.
Aug. 31, 1984	Syncom IV-2	Space Shuttle	Launched for Hughes Communication Service, Inc.
Sept. 1, 1984	Telstar-3C	Space Shuttle, PAM-D	Launched for American Telephone and Telegraph Co.
Sept. 21, 1984	Galaxy-3	Dalta 3920/PAM-D	Third in series, launched for Hughes Communications, Inc.
Nov. 9, 1984	Anik-D2	Space Shuttle, PAM-D	Launched for Telsat Canada.
Nov. 10, 1984	Syncom IV-1	Space Shuttle	Launched for Hughes Communication Service, Inc.
Nov. 14, 1984	NATO IIID	Delta 3914	NATO defense-related communications satellite.
WEATHER OBSERVATION [a]			
May 1, 1978	AMS 3	Thor-Burner 2	DoD meteorological satellite.
June 16, 1978	GOES 3	Thor-Delta (TAT)	Third of this series for NOAA.
Oct. 13, 1978	Tiros-N	Atlas F	First of third-generation for NOAA, also experimental satellite for NASA.
Oct. 24, 1978	Nimbus 7	Thor-Delta (TAT)	Last of this experimental series for NASA.
June 6, 1979	AMS 4	Atlas F	DoD meteorological satellite.
June 27, 1979	NOAA 6	Atlas F	Second of 8 planned third-generation satellites for NOAA; first was Tiros-N.
May 29, 1980	NOAA-B	Atlas F	Failed to achieve useful orbit.
Sept. 9, 1980	GOES 4	Thor-Delta (TAT)	Fourth of this series for NOAA.
May 22, 1981	GOES 5	Thor-Delta (TAT)	Fifth of polar-orbiting series for NOAA.
June 23, 1981	NOAA 7	Atlas F	Replacement for NOAA-B.
Dec. 21, 1982	DMSP F-6	Atlas E	DoD meterological satellite.
Mar. 28, 1983	NOAA 8	Atlas E	Joined NOAA 7 as part of 2-satellite operational system; launched for NOAA.
Apr. 28, 1983	GOES 6	Delta 3914	Launched for NOAA, operational as GOES-West.
Nov. 18, 1983	DMSP F-7	Atlas E	Second in block 5D-2 series, DoD meteorological satellite.
Dec. 12, 1984	NOAA-9	Atlas E	Launched for NOAA, to replace NOAA-7.
EARTH OBSERVATION			
Mar. 5, 1978	Landsat 3	Thor-Delta (TAT)	Third experimental earth resources satellite.
Apr. 26, 1978	HCMM (AEM 1)	Scout	Experimental, low-cost, limited-function heat-capacity mapping mission for earth resources.
June 27, 1978	Seasat 1	Atlas F	Proof-of-concept oceanographic-phenomena data-collection satellite.
July 16, 1982	Landsat 4	Thor-Delta (TAT)	Fourth experimental earth resources satellite. First use of thematic mapper (TM).
Mar. 1, 1984	Landsat-5	Delta 3920	Fifth experimental earth resources satellite, to replace ailing Landsat-4.
GEODESY			
Apr. 9, 1975	Geos 3	Thor-Delta (TAT)	To measure geometry and topography of ocean surface.
May 4, 1976	Lageos	Thor-Delta (TAT)	Laser geodynamic satellite.
NAVIGATION			
Feb. 22, 1978	Navstar 1	Atlas F	Global Positioning System satellite.
May 13, 1978	Navstar 2	Atlas F	Global Positioning System satellite.
Oct. 7, 1978	Navstar 3	Atlas F	Global Positioning System satellite.
Dec. 11, 1978	Navstar 4	Atlas F	Global Positioning System satellite.
Feb. 9, 1980	Navstar 5	Atlas F	Global Positioning System satellite.
Apr. 26, 1980	Navstar 6	Atlas F	Global Positioning System satellite.
May 15, 1981	Nova 1	Scout	First of improved Transit system satellites, for DoD.
July 14, 1983	Navstar 8	Atlas E	Global Positioning System satellite.
Feb. 5, 1984	IRT	Space Shuttle	Balloon to test Shuttle rendezvous radar.
June 13, 1984	Navstar-9	Atlas E	Global Positioning System satellite.
Sept. 8, 1984	Navstar-10	Atlas E	Global Positioning System satellite.
Oct. 12, 1984	Nova-3	Scout	Second of improved Transit system satellites, for DoD.

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[a] Does not include Department of Defense weather satellites that are not individually identified by launch.

APPENDIX B-2

U.S.-Launched Scientific Satellites 1978-1984

Date	Name	Launch Vehicle	Remarks
Jan. 26, 1978	IUE	Thor-Delta (TAT)	Ultraviolet observation of astronomical phenomena, in elliptical geosynchronous orbit.
July 14, 1978	Geos 2	Thor-Delta (TAT)	European studies of magnetosphere, in geosynchronous orbit.
Aug. 12, 1978	ISEE 3	Thor-Delta (TAT)	International Sun-Earth Explorer in halo orbit near earth-sun libration point; moved in 1983 to path to meet Comet Giacobini-Zinner in 1985.
Oct. 24, 1978	Cameo	Thor-Delta (TAT)	Barium and lithium cloud experiments, carried in rocket body of Nimbus 7 launcher.
Nov. 13, 1978	Heao 2	Atlas-Centaur	High-resolution observations of astronomical x-ray sources.
Jan. 30, 1979	Scatha	Thor-Delta (TAT)	Measurement of sources of electric charge buildup on spacecraft.
Feb. 18, 1979	Sage	Scout	Measurement of stratospheric aerosols and ozone.
Feb. 24, 1979	Solwind	Atlas F	Measurement of solar wind, electron buildup in polar regions, aerosols, and ozone.
June 6, 1979	Ariel 6	Scout	Measurement of cosmic radiation (United Kingdom payload).
Sept. 20, 1979	Heao 3	Atlas-Centaur	Gamma and cosmic ray emissions.
Oct. 30, 1979	Magsat	Scout	Detailed current description of earth's magnetic field and of sources of variations.
Feb. 14, 1980	SMM	Thor-Delta (TAT)	Solar Maximum Mission.
Aug. 3, 1981	Dynamics Explorers 1, 2	Thor-Delta (TAT)	DE 1 and 2 to measure magnetospheric-ionospheric energy coupling, electric currents and fields, plasmas.
Oct. 6, 1981	SME	Thor-Delta (TAT)	Solar Mesosphere Explorer to measure changes in mesospheric ozone.
Oct. 6, 1981	UOSAT (Oscar 9)	Thor-Delta (TAT)	Secondary payload with SME, for amateur radio and science experiments.
Jan. 26, 1983	IRAS	Delta 3910	Infrared sky survey.
May 26, 1983	EXOSAT	Delta 3914	European Space Agency study of x-ray sources.
June 22, 1983	SPAS 01	Space Shuttle	Reusable free-flying platform deployed and retrieved during STS 7; 6 scientific experiments from West Germany, 2 from ESA. NASA experiments tested spacecraft technology.
June 27, 1983	HILAT (P83-1)	Scout	Propagation effects of disturbed plasma on radar and communication systems, for DoD.
Apr. 6, 1984	Long Duration Exposure Facility (LDEF-1)	Space Shuttle	Scientific experiments designed for retrieval from space by Shuttle.
Aug. 16, 1984	Charge Composition Explorer (CCE)	Delta 3924	Measurement of earth's magnetosphere, one of three satellites composing Active Magnetosphere Particle Tracer Explorers Mission (AMPTE).
Aug. 16, 1984	Ion Release Module (IRM)	Delta 3924	Second of three satellites of AMPTE Mission, launched by same vehicle.
Aug. 16, 1984	United Kingdom Satellite (UKS)	Delta 3924	Third of three satellites of AMPTE Mission, launched by same vehicle.
Oct. 5, 1984	Earth Radiation Budget Satellite (ERBS)	Space Shuttle	First of three satellites in Earth Radiation Budget Experiment Research Program, NOAA-9 and NOAA-G carrying other instruments in Program.

APPENDIX B-3

U.S.-Launched Space Probes 1975-1984

Date	Name	Launch Vehicle	Remarks
Aug. 20, 1975	Viking 1	Titan IIIE-Centaur	Lander descended, landed safely on Mars on Plains of Chryse, Sept. 6 1976, while orbiter circled planet photographing it and relaying all data to Earth. Lander photographed its surroundings, tested soil samples for signs of life, and took measurements of atmosphere.
Sept. 9, 1975	Viking 2	Titan IIIE-Centaur	Lander descended, landed safely on Mars on Plains of Utopia, July 20, 1976, while orbiter circled planet photographing it and relaying all data to Earth. Lander photographed its surroundings, tested soil samples for signs of life, and took measurements of the atmosphere.
Jan. 15, 1976	Helios 2	Titan IIIE-Centaur	Flew in highly elliptical orbit to within 41 million km of sun, measuring solar wind, corona, electrons, and cosmic rays. Payload had same West German and U.S. experiments as Helios 1 plus cosmic-ray burst detector.
Aug. 20, 1977	Voyager 2	Titan IIIE-Centaur	Jupiter and Saturn flyby mission. Swung around Jupiter in July 1979, arrived Saturn in 1981, going on to Uranus by 1986, Neptune by 1989.
Sep. 5, 1977	Voyager 1	Titan IIIE-Centaur	Jupiter and Saturn flyby mission. Passing Voyager 2 on the way, swung around Jupiter in Mar. 1979, arrived at Saturn in Nov. 1980, headed for outer solar system.
May 20, 1978	Pioneer Venus 1	Atlas-Centaur	Venus orbiter; achieved Venus orbit Dec. 4, returning imagery and data.
Aug. 8, 1978	Pioneer Venus 2	Atlas-Centaur	Carried 1 large, 3 small probes plus spacecraft bus; all descended through Venus atmosphere Dec. 9, returned data.
None in 1984			

Appendix C

U.S. and Soviet Manned Spaceflights 1961–1984

Spacecraft	Launch Date	Crew	Flight Time (days : hrs : min)	Highlights
Vostok 1	Apr. 12, 1961	Yuriy A. Gagarin	0 : 1 : 48	First manned flight.
Mercury-Redstone 3	May 5, 1961	Alan B. Shepard, Jr.	0 : 0 : 15	First U.S. flight; suborbital.
Mercury-Redstone 4	July 21, 1961	Virgil I. Grissom	0 : 0 : 16	Suborbital; capsule sank after landing; astronaut safe.
Vostok 2	Aug. 6, 1961	German S. Titov	1 : 1 : 18	First flight exceeding 24 h.
Mercury-Atlas 6	Feb. 20, 1962	John H. Glenn, Jr.	0 : 4 : 55	First American to orbit.
Mercury-Atlas 7	May 24, 1962	M. Scott Carpenter	0 : 4 : 56	Landed 400 km beyond target.
Vostok 3	Aug. 11, 1962	Andriyan G. Nikolayev	3 : 22 : 25	First dual mission (with Vostok 4).
Vostok 4	Aug. 12, 1962	Pavel R. Popovich	2 : 22 : 59	Came within 6 km of Vostok 3.
Mercury-Atlas 8	Oct. 3, 1962	Walter M. Schirra, Jr.	0 : 9 : 13	Landed 8 km from target.
Mercury-Atlas 9	May 15, 1963	L. Gordon Cooper, Jr.	1 : 10 : 20	First U.S. flight exceeding 24 h.
Vostok 5	June 14, 1963	Valeriy F. Bykovskiy	4 : 23 : 6	Second dual mission (with Vostok 6).
Vostok 6	June 16, 1963	Valentina V. Tereshkova	2 : 22 : 50	First woman in space; within 5 km of Vostok 5.
Voskhod 1	Oct. 12, 1964	Vladimir M. Komarov Konstantin P. Feoktistov Boris G. Yegorov	1 : 0 : 17	First 3-man crew.
Voskhod 2	Mar. 18, 1965	Pavel I. Belyayev Aleksey A. Leonov	1 : 2 : 2	First extravehicular activity (Leonov, 10 min).
Gemini 3	Mar. 23, 1965	Virgil I. Grissom John W. Young	0 : 4 : 53	First U.S. 2-man flight; first manual maneuvers in orbit.
Gemini 4	June 3, 1965	James A. McDivitt Edward H. White II	4 : 1 : 56	21-min extravehicular activity (White).
Gemini 5	Aug. 21, 1965	L. Gordon Cooper, Jr. Charles Conrad, Jr.	7 : 22 : 55	Longest-duration manned flight to date.
Gemini 7	Dec. 4, 1965	Frank Borman James A. Lovell, Jr.	13 : 18 : 35	Longest-duration manned flight to date.
Gemini 6-A	Dec. 15, 1965	Walter M. Schirra, Jr. Thomas P. Stafford	1 : 1 : 51	Rendezvous within 30 cm of Gemini 7.
Gemini 8	Mar. 16, 1966	Neil A. Armstrong David R. Scott	0 : 10 : 41	First docking of 2 orbiting spacecraft (Gemini 8 with Agena target rocket).
Gemini 9-A	June 3, 1966	Thomas P. Stafford Eugene A. Cernan	3 : 0 : 21	Extravehicular activity; rendezvous.
Gemini 10	July 18, 1966	John W. Young Michael Collins	2 : 22 : 47	First dual rendezvous (Gemini 10 with Agena 10, then Agena 8).
Gemini 11	Sept. 12, 1966	Charles Conrad, Jr. Richard F. Gordon, Jr.	2 : 23 : 17	First initial-orbit docking; first tethered flight; highest earth-orbit altitude (1,372 km).
Gemini 12	Nov. 11, 1966	James A. Lovell, Jr. Edwin E. Aldrin, Jr.	3 : 22 : 35	Longest extravehicular activity to date (Aldrin, 5 hrs 37 min).
Soyuz 1	Apr. 23, 1967	Vladimir M. Komarov	1 : 2 : 37	Cosmonaut killed in reentry accident.
Apollo 7	Oct. 11, 1968	Walter M. Schirra, Jr. Donn F. Eisele R. Walter Cunningham	10 : 20 : 9	First U.S. 3-man mission.
Soyuz 3	Oct. 26, 1968	Georgiy T. Beregovoy	3 : 22 : 51	Maneuvered near unmanned Soyuz 2.
Apollo 8	Dec. 21, 1968	Frank Borman James A. Lovell, Jr. William A. Anders	6 : 3 : 1	First manned orbit(s) of moon; first manned departure from earth's sphere of influence; highest speed attained in manned flight to date.
Soyuz 4	Jan. 14, 1969	Vladimir A. Shatalov	2 : 23 : 23	Soyuz 4 and 5 docked and transferred 2 cosmonauts from Soyuz 5 to Soyuz 4.
Soyuz 5	Jan. 15, 1969	Boris V. Volynov Aleksey S. Yeliseyev Yevgeniy V. Khrunov	3 : 0 : 56	
Apollo 9	Mar. 3, 1969	James A. McDivitt David R. Scott Russell L. Schweickart	10 : 1 : 1	Successfully simulated in earth orbit operation of lunar module to landing and takeoff from lunar surface and rejoining with command module.
Apollo 10	May 18, 1969	Thomas P. Stafford John W. Young Eugene A. Cernan	8 : 0 : 3	Successfully demonstrated complete system including lunar module descent to 14,300 m from the lunar surface.
Apollo 11	July 16, 1969	Neil A. Armstrong Michael Collins Edwin E. Aldrin, Jr.	8 : 3 : 9	First manned landing on lunar surface and safe return to earth. First return of rock and soil samples to earth, and manned deployment of experiments on lunar surface.
Soyuz 6	Oct. 11, 1969	Georgiy Shonin Valeriy N. Kubasov	4 : 22 : 42	Soyuz 6, 7, and 8 operated as a group flight without actually docking. Each conducted certain experiments, including welding and earth and celestial observation.
Soyuz 7	Oct. 12, 1969	Anatoliy V. Filipchenko Viktor N. Gorbatko Vladislav N. Volkov	4 : 22 : 41	
Soyuz 8	Oct. 13, 1969	Vladimir A. Shatalov Aleksey S. Yeliseyev	4 : 22 : 50	

APPENDIX C—Continued

U.S. and Soviet Manned Spaceflights 1961-1984

Spacecraft	Launch Date	Crew	Flight Time (days : hrs : min)	Highlights
Apollo 12	Nov. 14, 1969	Charles Conrad, Jr. Richard F. Gordon, Jr. Alan L. Bean	10 : 4 : 36	Second manned lunar landing. Explored surface of moon and retrieved parts of Surveyor 3 spacecraft, which landed in Ocean of Storms on Apr. 19, 1967.
Apollo 13	Apr. 11, 1970	James A. Lovell, Jr. Fred W. Haise, Jr. John L. Swigert, Jr.	5 : 22 : 55	Mission aborted; explosion in service module. Ship circled moon, with crew using LM as "lifeboat" until just before reentry.
Soyuz 9	June 1, 1970	Andriyan G. Nikolayev Vitaliy I. Sevastyanov	17 : 16 : 59	Longest manned spaceflight to date.
Apollo 14	Jan. 31, 1971	Alan B. Shepard, Jr. Stuart A. Roosa Edgar D. Mitchell	9 : 0 : 2	Third manned lunar landing. Mission demonstrated pinpoint landing capability and continued manned exploration.
Soyuz 10	Apr. 22, 1971	Vladimir A. Shatalov Aleksey S. Yeliseyev Nikolay N. Rukavishnikov	1 : 23 : 46	Docked with Salyut 1, but crew did not board space station launched 19 Apr. Crew recovered Apr. 24, 1971.
Soyuz 11	June 6, 1971	Georgiy T. Dobrovolskiy Vladislav N. Volkov Viktor I. Patsayev	23 : 18 : 22	Docked with Salyut 1 and Soyuz 11 crew occupied space station for 22 days. Crew perished during final phase of Soyuz 11 capsule recovery on June 30, 1971.
Apollo 15	July 26, 1971	David R. Scott Alfred M. Worden James B. Irwin	12 : 7 : 12	Fourth manned lunar landing and first Apollo "J" series mission, which carried Lunar Roving Vehicle. Worden's inflight EVA of 38 min 12 sec was performed during return trip.
Apollo 16	Apr. 16, 1972	John W. Young Charles M. Duke, Jr. Thomas K. Mattingly II	11 : 1 : 51	Fifth manned lunar landing, with Lunar Roving Vehicle.
Apollo 17	Dec. 7, 1972	Eugene A. Cernan Harrison H. Schmitt Ronald E. Evans	12 : 13 : 52	Sixth and final Apollo manned lunar landing, again with roving vehicle.
Skylab 2	May 25, 1973	Charles Conrad, Jr. Joseph P. Kerwin Paul J. Weitz	28 : 0 : 50	Docked with Skylab 1 (launched unmanned May 14) for 28 days. Repaired damaged station.
Skylab 3	July 28, 1973	Alan L. Bean Jack R. Lousma Owen K. Garriott	59 : 11 : 9	Docked with Skylab 1 for more than 59 days.
Soyuz 12	Sept. 27, 1973	Vasiliy G. Lazarev Oleg G. Makarov	1 : 23 : 16	Checkout of improved Soyuz.
Skylab 4	Nov. 16, 1973	Gerald P. Carr Edward G. Gibson William R. Pogue	84 : 1 : 16	Docked with Skylab 1 in long-duration mission; last of Skylab program.
Soyuz 13	Dec. 18, 1973	Petr I. Klimuk Valentin V. Lebedev	7 : 20 : 55	Astrophysical, biological, and earth resources experiments.
Soyuz 14	July 3, 1974	Pavel R. Popovich Yuriy P. Artyukhin	15 : 17 : 30	Docked with Salyut 3 and Soyuz 14 crew occupied space station.
Soyuz 15	Aug. 26, 1974	Gennadiy V. Sarafanov Lev S. Demin	2 : 0 : 12	Rendezvoused but did not dock with Salyut 3.
Soyuz 16	Dec. 2, 1974	Anatoliy V. Filipchenko Nikolay N. Rukavishnikov	5 : 22 : 24	Test of ASTP configuration.
Soyuz 17	Jan. 10, 1975	Aleksey A. Gubarev Georgiy M. Grechko	29 : 13 : 20	Docked with Salyut 4 and occupied station.
Anomaly	Apr. 5, 1975	Vasiliy G. Lazarev Oleg G. Makarov	0 : 0 : 20	Soyuz stages failed to separate; crew recovered after abort.
Soyuz 18	May 24, 1975	Petr I. Klimuk Vitaliy I. Sevastyanov	62 : 23 : 20	Docked with Salyut 4 and occupied station.
Soyuz 19	July 15, 1975	Aleksey A. Leonov Valeriy N. Kubasov	5 : 22 : 31	Target for Apollo in docking and joint experiments of ASTP mission.
Apollo (ASTP)	July 15, 1975	Thomas P. Stafford Donald K. Slayton Vance D. Brand	9 : 1 : 28	Docked with Soyuz 19 in joint experiments of ASTP mission.
Soyuz 21	July 6, 1976	Boris V. Volynov Vitaliy M. Zholobov	48 : 1 : 32	Docked with Salyut 5 and occupied station.
Soyuz 22	Sept. 15, 1976	Valeriy F. Bykovskiy Vladimir V. Aksenov	7 : 21 : 54	Earth resources study with multispectral camera system.

Appendix C—Continued

U.S. and Soviet Manned Spaceflights 1961-1984

Spacecraft	Launch Date	Crew	Flight Time (days : hrs : min)	Highlights
Soyuz 23	Oct. 14, 1976	Vyacheslav D. Zudov Valeriy I. Rozhdestvenskiy	2 : 0 : 6	Failed to dock with Salyut 5.
Soyuz 24	Feb. 7, 1977	Viktor V. Gorbatko Yuriy N. Glazkov	17 : 17 : 23	Docked with Salyut 5 and occupied station.
Soyuz 25	Oct. 9, 1977	Vladimir V. Kovalenok Valeriy V. Ryumin	2 : 0 : 46	Failed to achieve hard dock with Salyut 6 station.
Soyuz 26	Dec. 10, 1977	Yuriy V. Romanenko Georgiy M. Grechko	37 : 10 : 6	Docked with Salyut 6. Crew returned in Soyuz 27; crew duration 96 days 10 hrs.
Soyuz 27	Jan. 10, 1978	Vladimir A. Dzhanibekov Oleg G. Makarov	64 : 22 : 53	Docked with Salyut 6. Crew returned in Soyuz 26; crew duration 5 days 22 hrs 59 min.
Soyuz 28	Mar. 2, 1978	Aleksey A. Gubarev Vladimir Remek	7 : 22 : 17	Docked with Salyut 6. Remek was first Czech cosmonaut to orbit.
Soyuz 29	June 15, 1978	Vladimir V. Kovalenok Aleksandr S. Ivanchenkov	79 : 15 : 23	Docked with Salyut 6. Crew returned in Soyuz 31; crew duration 139 days 14 hrs 48 min.
Soyuz 30	June 27, 1978	Petr I. Klimuk Miroslaw Hermaszewski	7 : 22 : 4	Docked with Salyut 6. Hermaszewski was first Polish cosmonaut to orbit.
Soyuz 31	Aug. 26, 1978	Valeriy F. Bykovskiy Sigmund Jaehn	67 : 20 : 14	Docked with Salyut 6. Crew returned in Soyuz 29; crew duration 7 days 20 hrs 49 min. Jaehn was first German Democratic Republic cosmonaut to orbit.
Soyuz 32	Feb. 25, 1979	Vladimir A. Lyakhov Valeriy V. Ryumin	108 : 4 : 24	Docked with Salyut 6. Crew returned in Soyuz 34; crew duration 175 days 36 min.
Soyuz 33	Apr. 10, 1979	Nikolay N. Rukavishnikov Georgi I. Ivanov	1 : 23 : 1	Failed to achieve docking with Salyut 6 station. Ivanov was first Bulgarian cosmonaut to orbit.
Soyuz 34	June 6, 1979	(unmanned at launch)	73 : 18 : 17	Docked with Salyut 6, later served as ferry for Soyuz 32 crew while Soyuz 32 returned unmanned.
Soyuz 35	Apr. 9, 1980	Leonid I. Popov Valeriy V. Ryumin	55 : 1 : 29	Docked with Salyut 6. Crew returned in Soyuz 37. Crew duration, 184 days 20 hrs 12 min.
Soyuz 36	May 26, 1980	Valeriy N. Kubasov Bertalan Farkas	65 : 20 : 54	Docked with Salyut 6. Crew returned in Soyuz 35. Crew duration 7 days 20 hrs 46 min. Farkas was first Hungarian to orbit.
Soyuz T-2	June 5, 1980	Yuriy V. Malyshev Vladimir V. Aksenov	3 : 22 : 21	Docked with Salyut 6. First manned flight of new-generation ferry.
Soyuz 37	July 23, 1980	Viktor V. Gorbatko Pham Tuan	79 : 15 : 17	Docked with Salyut 6. Crew returned in Soyuz 36. Crew duration 7 days 20 hrs 42 min. Pham was first Vietnamese to orbit.
Soyuz 38	Sept. 18, 1980	Yuriy V. Romanenko Arnaldo Tamayo Mendez	7 : 20 : 43	Docked with Salyut 6. Tamayo was first Cuban to orbit.
Soyuz T-3	Nov. 27, 1980	Leonid D. Kizim Oleg G. Makarov Gennadiy M. Strekalov	12 : 19 : 8	Docked with Salyut 6. First 3-man flight in Soviet program since 1971.
Soyuz T-4	Mar. 12, 1981	Vladimir V. Kovalenok Viktor P. Savinykh	74 : 18 : 38	Docked with Salyut 6.
Soyuz 39	Mar. 22, 1981	Vladimir A. Dzhanibekov Jugderdemidiyn Gurragcha	7 : 20 : 43	Docked with Salyut 6. Gurragcha first Mongolian cosmonaut to orbit.
Space Shuttle Columbia (STS 1)	Apr. 12, 1981	John W. Young Robert L. Crippen	2 : 6 : 21	First flight of Space Shuttle, tested spacecraft in orbit. First landing of airplanelike craft from orbit for reuse.
Soyuz 40	May 14, 1981	Leonid I. Popov Dumitru Prunariu	7 : 20 : 41	Docked with Salyut 6. Prunariu first Romanian cosmonaut to orbit.
Space Shuttle Columbia (STS 2)	Nov. 12, 1981	Joe H. Engle Richard H. Truly	2 : 6 : 13	Second flight of Space Shuttle, first scientific payload (OSTA 1). Tested remote manipulator arm. Returned for reuse.
Space Shuttle Columbia (STS 3)	Mar. 22, 1982	Jack R. Lousma C. Gordon Fullerton	8 : 4 : 49	Third flight of Space Shuttle, second scientific payload (OSS 1). Second test of remote manipulator arm. Flight extended 1 day because of flooding at primary landing site; alternate landing site used. Returned for reuse.
Soyuz T-[illegible]	May 13, 1982	Anatoliy Berezovoy Valentin Lebedev	211 : 9 : 5	Docked with Salyut 7. Crew duration of 211 days. Crew returned in Soyuz T-7.

U.S. and Soviet Manned Spaceflights 1961–1984

Spacecraft	Launch Date	Crew	Flight Time (days : hrs : min)	Highlights
Soyuz T-6	June 24, 1982	Vladimir Dzhanibekov Aleksandr Ivanchenkov Jean-Loup Chretien	7 : 21 : 51	Docked with Salyut 7. Chretien first French cosmonaut to orbit.
Space Shuttle Columbia (STS 4)	June 27, 1982	Thomas K. Mattingly II Henry W. Hartsfield, Jr.	7 : 1 : 9	Fourth flight of Space Shuttle, first DoD payload, additional scientific payloads. Returned July 4. Completed orbital flight testing program. Returned for reuse.
Soyuz T-7	Aug. 19, 1982	Leonid Popov Aleksandr Serebrov Svetlana Savitskaya	7 : 21 : 52	Docked with Salyut 7. Savitskaya second Soviet woman to orbit. Crew returned in Soyuz T-5.
Space Shuttle Columbia (STS 5)	Nov. 11, 1982	Vance D. Brand Robert F. Overmyer Joseph P. Allen William B. Lenoir	5 : 2 : 14	Fifth flight of Space Shuttle, first operational flight; launched 2 commercial satellites (SBS 3 and Anik C-3); first flight with 4 crewmembers. EVA test canceled when spacesuits malfunctioned.
Space Shuttle Challenger (STS 6)	Apr. 4, 1983	Paul J. Weitz Karol J. Bobko Donald H. Peterson Story Musgrave	5 : 0 : 24	Sixth flight of Space Shuttle, launched TDRS 1.
Soyuz T-8	Apr. 20, 1983	Vladimir Titov Gennady Strekalov Aleksander Serebrov	2 : 0 : 18	Failed to achieve docking with Salyut 7 station.
Space Shuttle Challenger (STS 7)	June 18, 1983	Robert L. Crippen Frederick H. Hauck John M. Fabian Sally K. Ride Norman T. Thagard	6 : 2 : 24	Seventh flight of Space Shuttle, launched 2 commercial satellites (Anik C-2 and Palapa B-1), also launched and retrieved SPAS 01; first flight with 5 crewmembers, including first woman U.S. astronaut.
Soyuz T-9	June 28, 1983	Vladimir Lyakhov Aleksandr Aleksandrov	149 : 9 : 46	Docked with Salyut 7 station.
Space Shuttle Challenger (STS 8)	Aug. 30, 1983	Richard H. Truly Daniel C. Brandenstein Dale A. Gardner Guion S. Bluford, Jr. William E. Thornton	6 : 1 : 9	Eighth Flight of Space Shuttle, launched one commercial satellite (Insat 1-B), first flight of U.S. black astronaut
Space Shuttle Columbia (STS 9)	Nov. 28, 1983	John W. Young Brewster W. Shaw Owen K. Garriott Robert A. R. Parker Byron K. Lichtenberg Ulf Merbold	10 : 7 : 47	Ninth flight of Space Shuttle, first flight of Spacelab 1, first flight of 6 crewmembers, one of whom was West German, first non-U.S. astronaut to fly in U.S. space program.
Space Shuttle Challenger (STS-41B)	Feb. 3, 1984	Vance D. Brand Robert L. Gibson Bruce McCandless Ronald E. McNair Robert L. Stewart	7 : 23 : 16	Tenth flight of Space Shuttle, two communication satellites failed to achieve orbit. First use of Manned Maneuvering Unit (MMU) in space.
Soyuz T-10	Feb. 8, 1984	Leonid Kizim Vladimir Solovev Oleg Atkov	62 : 22 : 43	Docked with Salyut 7 station. Crew set space duration record of 237 days. Crew returned in Soyuz T-11.
Soyuz T-11	Apr. 3, 1984	Yuriy Malyshev Gennadiy Strekalov Rakesh Sharma	181 : 21 : 48	Docked with Salyut 7 station. Sharma first Indian in space. Crew returned in Soyuz T-10.
Space Shuttle Challenger (STS-41C)	Apr. 6, 1984	Robert L. Crippen Frances R. Scobee Terry J. Hart George D. Nelson James D. Van Hoften	6 : 23 : 41	Eleventh flight of Space Shuttle, deployment of LDEF-1, for later retrieval, Solar Maximum Satellite retrieved, repaired, and redeployed.
Soyuz T-12	July 17, 1984	Vladmir Dzhanibekov Svetlana Savistskaya Igor Volk	11 : 19 : 14	Docked with Salyut 7 station. First woman extravehicular activity.
Space Shuttle Discovery (STS-41D)	Aug, 30, 1984	Henry W. Hartsfield Michael L. Coats Richard M. Mullane Steven A. Hawley Judith A. Resnick Charles D. Walker	6 : : 56	Twelfth flight of Space Shuttle. First flight of U.S. non-astronaut.

APPENDIX C—Continued

U.S. and Soviet Manned Spaceflights 1961-1984

Spacecraft	Launch Date	Crew	Flight Time (days : hrs : min)	Highlights
Space Shuttle Challenger (STS-41G)	Sept. 5, 1984	Robert L. Crippen Jon A. McBride Kathryn D. Sullivan Sally K. Ride David Leestma Paul D. Scully-Power Marc Garneau	8 : 5 : 24	Thirteenth flight of Space Shuttle, first flight of 7 crewmembers, including first flight of two U.S. women and one Canadian.
Space Shuttle Discovery (STS-51A)	Nov. 8, 1984	Frederick H. Hauck David M. Walker Joseph P. Allen Anna L. Fisher Dale A. Gardner	7 : 23 : 45	Fourteenth flight of Space Shuttle, first retrieval and return of two disabled communications satellites (Westar 6, Palapa B2) to earth.

APPENDIX D

U.S. Space Launch Vehicles

Vehicle	Stages	Propellant[a]	Thrust (kilo-newtons)	Max. Dia. × Height (m)	Max. Payload (kg)[b]			First Launch[c]
					185-Km Orbit	Geosynch.-Transfer Orbit	Circular Sun-Synch. Orbit	
Scout	1. Algol IIIA	Solid	431.1	1.14 × 22.9	255 205[d]	–	155[d]	1979(60)
	2. Castor IIA	Solid	285.2					
	3. Antares IIIA	Solid	83.1					
	4. Altair IIIA	Solid	25.6					
Delta 2900 Series (Thor-Delta)	1. Thor plus	LOX/RP-1	912.0	2.44 × 35.4	2,000 1,410[d]	705	1,250[d]	1973(60)
	9 TX 354-5	Solid	147 each					
	2. Delta	N_2O_4/Aerozine-50	44.2					
	3. TE 364-4	Solid	65.8					
Delta 3900 Series (Thor-Delta)[e]	1. Thor plus	LOX/RP-1	912.0	2.44 × 35.4	3,045 2,180[d]	1,275	2,135[d]	1982(60)
	9 TX 526-2	Solid	375 each					
	2. Delta	N_2O_4/Aerozine-50	44.2					
Atlas E	1. Atlas booster & sustainer	LOX/RP-1	1,722.0	3.05 × 28.1	2,090[d][f]	–	1,500[d]	1972(67)
Atlas-Centaur	1. Atlas booster & sustainer	LOX/RP-1	1,913.0	3.05 × 45.0	6,100	2,360	–	1984(62)
	2. Centaur	LOX/LH_2	146.0					
					185-Km Orbit	Direct Geosynch. Orbit	Sun-Synch. Transfer Orbit	
Titan IIIB-Agena	1. LR-87	N_2O_4/Aerozine	2,341.0	3.05 × 48.4	3,600[d]	–	3,060[d]	1966
	2. LR-91	N_2O_4/Aerozine	455.1					
	3. Agena	IRFNA/UDMH	71.2					
Titan III(34)D/IUS	1. Two 5½-segment, 3.05 m dia	Solid	11,564.8	3.05 × 48.0	14,920	1,850[d]	–	1982
	2. LR-87	N_2O_4/Aerozine	2,366.3					
	3. LR-91	N_2O_4/Aerozine	449.3					
	4. IUS 1st stage	Solid	275.8					
	5. IUS 2nd stage	Solid	115.7					
Titan III(34)D/Transtage	Same as Titan III(34)D plus:			3.05 × 46.9	14,920	1,855[d]	–	1984[h]
	4. Transtage	N_2O_4/Aerozine	69.8					
					280- to 420-Km Orbit			
Space Shuttle (reusable)	1. Orbiter; 3 main engines (SSMEs) fire in parallel with SRBs	LOX/LH_2	1,670 each	23.79 × 37.24 wing long span	29,500 in full performance configuration			1981
	2. Two-solid-fueled rocket boosters (SRBs) fire in parallel with SSMEs	AL/NH_4CLO_4/PBAN	11,790 each	3.71 × 45.45				
	Mounted on external tank (ET)			8.40 × 46.88				

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[a] Propellant abbreviations used are as follows: liquid oxygen and a modified kerosene = LOX/RP,RJ; solid propellant combining in a single mixture both fuel and oxidizer = Solid; inhibited red-fuming nitric acid and unsymmetrical dimethylhydrazine = IRFNA/UDMH; nitrogen tetroxide and $UDMH/N_2H_4$ = N_2O_4/aerozine; liquid oxygen and liquid hydrogen = LOX/LH_2; aluminum, ammonium perchlorate, and polybutadiene acrolonitrile terpolymer = AL/NH_4CLO_4/PBAN.

[b] Due east launch except as indicated.

[c] The date of first launch applies to this latest modification with a date in parentheses for the initial version.

[d] Polar launch.

[e] Maximum performance based on 3920, 3920/PAM configurations. PAM = payload assist module (a private venture).

[f] With dual TE 364-4.

[g] With 96° flight azimuth.

[h] Initial operational capability in December 1982; launch to be scheduled as needed.

NOTE. Data should not be used for detailed NASA mission planning without concurrence of the director of Space Transportation System Support Programs.

APPENDIX E-1

Space Activities of the U.S. Government

HISTORICAL BUDGET SUMMARY—BUDGET AUTHORITY

(in millions of dollars)

Fiscal Year	NASA		Defense	Energy	Commerce	Interior	Agriculture	NSF	Total Space
	Total	Space[a]							
1959	330.9	260.9	489.5	34.3	...	...	...	...	784.7
1960	523.6	461.5	560.9	43.3	...	...	...	0.1	1,065.8
1961	964.0	926.0	813.9	67.7	...	...	...	.6	1,808.2
1962	1,824.9	1,796.8	1,298.2	147.8	50.7	...	...	1.3	3,294.8
1963	3,673.0	3626.0	1,549.9	213.9	43.2	...	...	1.5	5,434.5
1964	5,099.7	5,016.3	1,599.3	210.0	2.8	...	...	3.0	6,831.4
1965	5,249.7	5,137.6	1,573.9	228.6	12.2	...	...	3.2	6,955.5
1966	5,174.9	5,064.5	1,688.8	186.8	26.5	...	...	3.2	6,969.8
1967	4,965.6	4,830.2	1,663.6	183.6	29.3	...	...	2.8	6,709.5
1968	4,587.3	4,430.0	1,921.8	145.1	28.1	0.2	0.5	3.2	6,528.9
1969	3,990.9	3,822.0	2,013.0	118.0	20.0	.2	.7	1.9	5,975.8
1970	3,745.8	3,547.0	1,678.4	102.8	8.0	1.1	.8	2.4	5,340.5
1971	3,311.2	3,101.3	1,512.3	94.8	27.4	1.9	.8	2.4	4,740.9
1972	3,306.6	3,071.0	1,407.0	55.2	31.3	5.8	1.6	2.8	4,574.7
1973	3,406.2	3,093.2	1,623.0	54.2	39.7	10.3	1.9	2.6	4,824.9
1974	3,036.9	2,758.5	1,766.0	41.7	60.2	9.0	3.1	1.8	4,640.3
1975	3,229.1	2,915.3	1,892.4	29.6	64.4	8.3	2.3	2.0	4,914.3
1976	3,550.3	3,225.4	1,983.3	23.3	71.5	10.4	3.6	2.4	5,319.9
Transitional Quarter	931.8	849.2	460.4	4.6	22.2	2.6	.9	.6	1,340.5
1977	3,817.8	3,440.2	2,411.9	21.7	90.8	9.5	6.3	2.4	5,982.8
1978	4,060.1	3,622.9	2,738.3	34.4	102.8	9.7	7.7	2.4	6,518.2
1979	4,595.5	4,030.4	3,035.6	58.6	98.4	9.9	8.2	2.4	7,243.5
1980	5,240.2	4,680.4	3,848.4	39.6	92.6	11.7	13.7	2.4	8,688.8
1981	5,518.4	4,992.4	4,827.7	40.5	87.0	12.3	15.5	2.4	9,977.8
1982	6,043.9[b]	5,527.6	6,678.7	60.6	144.5	12.1	15.2	2.0	12,440.7
1983	6,875.3[c]	6,327.9	9,018.9	38.9	177.8	4.6	20.4	0.0[d]	15,588.5
1984	7,248.0	6,648.3	10,194.9	34.1	236.0	3.0	19.4	0.0	17,135.7
1985 est.	7,510.7	6,881.4	12,813.8	36.7	373.6	2.8	13.2	0.0	20,121.5
1986 est.	7,886.0	7,263.9	15,846.5	37.0	364.5	3.6	13.4	0.0	23,528.9

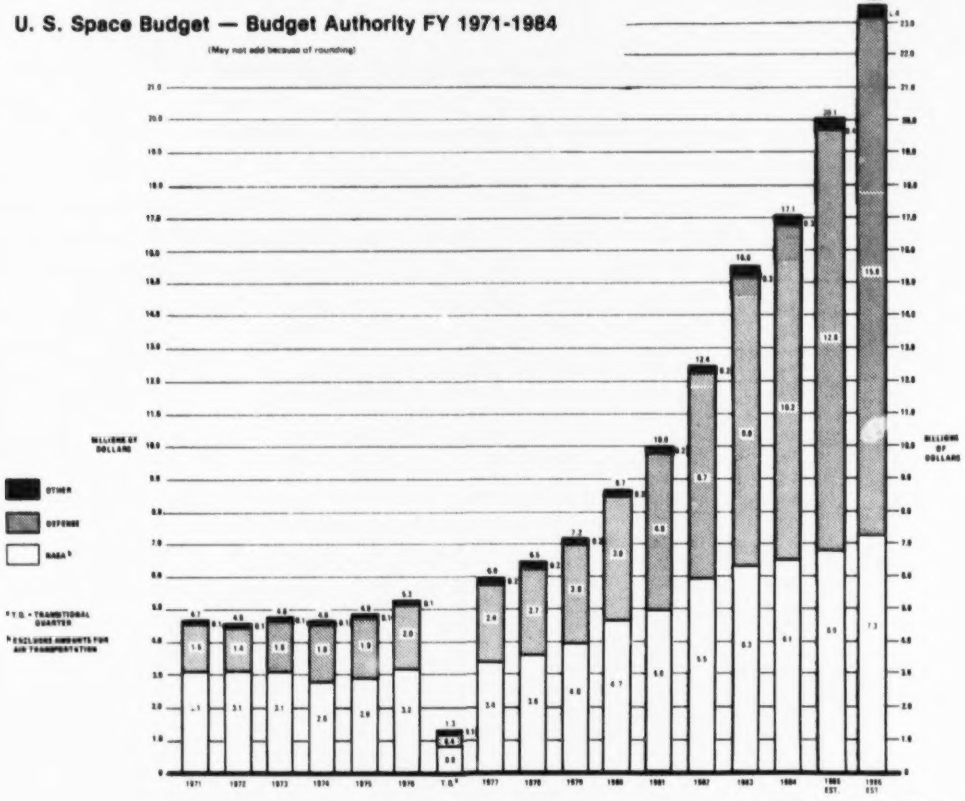
[a] Excludes amounts for air transportation (subfunction 402).

[b] Includes $33.5 million unobligated funds that lapsed.

[c] Includes $37.6 million for reappropriation of prior year funds.

[d] NSF funding of balloon research transferred to NASA.

SOURCE: Office of Management and Budget.



U. S. Space Budget — Budget Authority FY 1971-1984

(May not add because of rounding)

SOURCE: OFFICE OF MANAGEMENT AND BUDGET

APPENDIX E-2

Space Activities Budget

(in millions of dollars by fiscal year)

Federal Space Programs	Budget Authority 1984 Actual	Budget Authority 1985 Estimate	Budget Authority 1986 Estimate	Budget Outlays 1984 Actual	Budget Outlays 1985 Estimate	Budget Outlays 1986 Estimate
Federal agencies:						
NASA[a]	6,648.3	6,881.4	7,263.9	6,461.4	6,690.3	7,155.7
Defense	10,194.9	12,813.8	15,846.5	8,000.2	10,444.3	13,067.2
Energy	34.1	36.7	37.0	33.4	38.0	37.0
Commerce	236.0	373.6	364.5	208.7	374.3	287.7
Interior	3.0	2.8	3.6	3.0	2.7	3.7
NSF[b]	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture	19.4	13.2	13.4	19.4	13.2	13.4
Total	17,135.7	20,121.5	23,528.9	14,726.1	17,562.8	20,564.7
NASA:						
Space flight	4,101.1	3,901.8	4,022.0	4,028.2	3,914.4	4,004.0
Space science, applications, and technology	1,747.0	2,021.3	2,264.9	1,686.9	1,890.2	2,144.4
Air transportation	599.7	633.3	622.1	586.3	630.6	615.9
Supporting operations	800.2	954.3	977.0	746.3	885.7	1,007.2
Total NASA	7,248.0	7,510.7	7,886.0	7,047.7	7,320.9	7,771.5

SOURCE: Office of Management and Budget.

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[a] Excludes amounts for air transportation. Includes $37.6 million for reappropriation of prior year funds.

[b] NSF funding for balloon research transferred to NASA.

APPENDIX E-3

Aeronautics Budget

(in millions of dollars by fiscal year)

Federal Aeronautics Programs	Budget Authority			Budget Outlays		
	1984 Actual	1985 Estimate	1986 Estimate	1984 Actual	1985 Estimate	1986 Estimate
NASA[a]	599.7	633.3	622.1	586.3	630.7	616.0
Department of Defense[b]	3,224.0	3,433.0	4,868.0	2,994.4	3,177.0	4,048.5
Department of Transportation[c]	263.5	265.0	196.5	146.2	300.0	196.1
Total	4,087.2	4,331.3	5,686.6	3,726.9	4,107.7	4,860.6

[a] Research and Development, Construction of Facilities, Research and Program Management.

[b] Research, Development, Testing, and Evaluation of aircraft and related equipment.

[c] Federal Aviation Administration: Research, Engineering, and Development; Facilities, Engineering, and Development.

SOURCE: Office of Management and Budget.

APPENDIX F-1

State of the Union Address
Space Station

Excerpt from Address Delivered Before a Joint Session of the Congress. January 25, 1984

Nowhere is this more important than our next frontier: space. Nowhere do we so effectively demonstrate our technological leadership and ability to make life better on Earth. The Space Age is barely a quarter of a century old. But already we've pushed civilization forward with our advances in science and technology. Opportunities and jobs will multiply as we cross new thresholds of knowledge and reach deeper into the unknown.

Our progress in space—taking giant steps for all mankind—is a tribute to American teamwork and excellence. Our finest minds in government, industry, and academia have all pulled together. And we can be proud to say: We are first; we are the best; and we are so because we're free.

America has always been greatest when we dared to be great. We can reach for greatness again. We can follow our dreams to distant stars, living and working in space for peaceful, economic, and scientific gain. Tonight, I am directing NASA to develop a permanently manned space station and to do it within a decade.

A space station will permit quantum leaps in our reach in science, communications, in metals, and in lifesaving medicines which could be manufactured only in space. We want our friends to help us meet these challenges and share in their benefits. NASA will invite other countries to participate so we can strengthen peace, build prosperity, and expand freedom for all who share our goals.

Just as the oceans opened up a new world for clipper ships and Yankee traders, space holds enormous potential for commerce today. The market for space transportation could surpass our capacity to develop it. Companies interested in putting payloads into space must have ready access to private sector launch services. The Department of Transportation will help an expendable launch services industry to get off the ground. We'll soon implement a number of executive initiatives, develop proposals to ease regulatory constraints, and, with NASA's help, promote private sector investment in space.

APPENDIX F-2

Commercial Expendable Launch Vehicle Activities
Executive Order 12465 (February 24, 1984)

By the authority vested in me as President by the Constitution and laws of the United States of America, and in order to encourage, facilitate and coordinate the development of commercial expendable launch vehicle (ELV) operations by private United States enterprises, it is hereby ordered as follows:

Section 1. The Department of Transportation is designated as the lead agency within the Federal government for encouraging and facilitating commercial ELV activities by the United States private sector.

Sec. 2. *Responsibilties of Lead Agency.* The Secretary of Transportation shall, to the extent permitted by law and subject to the availability of appropriations, perform the following functions:

(a) act as a focal point within the Federal government for private sector space launch contacts related to commercial ELV operations;

(b) promote and encourage commercial ELV operations in the same manner that other private United States commercial enterprises are promoted by United States agencies;

(c) provide leadership in the establishment, within affected departments and agencies, of procedures that expedite the processing of private sector requests to obtain licenses necessary for commercial ELV launches and the establishment and operation of commercial launch ranges;

(d) consult with other affected agencies to promote consistent application of ELV licensing requirements for the private sector and assure fair and equitable treatment for all private sector applicants;

(e) serve as a single point of contact for collection and dissemination of documentation related to commercial ELV licensing applications;

(f) make recommendations to affected agencies and, as appropriate, to the President, concerning administrative measures to streamline Federal government procedures for licensing of commercial ELV activities;

(g) identify Federal Statutes, treaties, regulations and policies which may have an adverse impact on ELV commercialization efforts and recommend appropriate changes to affected agencies and, as appropriate, to the President; and

(h) conduct appropriate planning regarding long-term effects of Federal activities related to ELV commercialization.

Sec. 3. An interagency group, chaired by the Secretary of Transportation and composed of representatives from the Department of State, the Department of Defense, the Department of Commerce, the Federal Communications Commission, and the National Aeronautics and Space Administration, is hereby established. This group shall meet at the call of the Chair and shall advise and assist the Department of Transportation in performing its responsibilities under this Order.

Sec. 4. Responsibilities of Other Agencies. All executive departments and agencies shall assist the Secretary of Transportation in carrying out this Order. To the extent permitted by law and in consultation with the Secretary of Transportation, they shall:

(a) provide the Secretary of Transportation with information concerning agency regulatory actions which may affect development of commercial ELV operations;

(b) review and revise their regulations and procedures to eliminate unnecessary regulatory obstacles to the development of commercial ELV operations and to ensure that those regulations and procedures found essential are administered as efficiently as possible; and

(c) establish timetables for the expeditious handling of and response to applications for licenses and approvals for commercial ELV activities.

Sec. 5. The powers granted to the Secretary of Transportation to encourage, facilitate and coordinate the overall ELV commercialization process shall not diminish or abrogate any statutory or operational authority exercised by any other Federal agency.

Sec. 6. Nothing contained in this Order or in any procedures promulgated hereunder shall confer any substantive or procedural right or privilege on any person or organization, enforceable against the United States, its agencies, its officers or any person.

Sec. 7. This Order shall be effective immediately.

Ronald Reagan

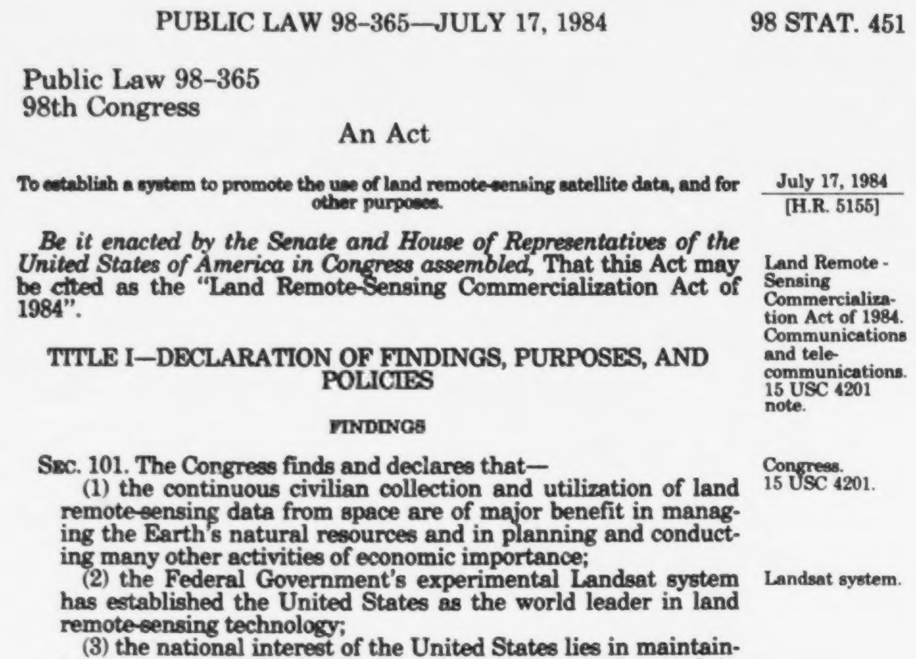
The White House,
February 24, 1984.

[*Filed with the Office of the Federal Register, 3:25 p.m., February 24, 1984*]

APPENDIX F-3

Public Law 98-365—July 17, 1984
98th Congress

An Act to establish a system to promote the use of land remote-sensing satellite data, and for other purposes.



Public Law 98-365
98th Congress

An Act

To establish a system to promote the use of land remote-sensing satellite data, and for other purposes.

July 17, 1984
[H.R. 5155]

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "Land Remote-Sensing Commercialization Act of 1984".

Land Remote-Sensing Commercialization Act of 1984. Communications and telecommunications. 15 USC 4201 note.

TITLE I—DECLARATION OF FINDINGS, PURPOSES, AND POLICIES

FINDINGS

Congress. 15 USC 4201.

SEC. 101. The Congress finds and declares that—

(1) the continuous civilian collection and utilization of land remote-sensing data from space are of major benefit in managing the Earth's natural resources and in planning and conducting many other activities of economic importance;

Landsat system.

(2) the Federal Government's experimental Landsat system has established the United States as the world leader in land remote-sensing technology;

(3) the national interest of the United States lies in maintaining international leadership in civil remote sensing and in broadly promoting the beneficial use of remote-sensing data;

Defense and national security.

(4) land remote sensing by the Government or private parties of the United States affects international commitments and policies and national security concerns of the United States;

(5) the broadest and most beneficial use of land remote-sensing data will result from maintaining a policy of nondiscriminatory access to data;

(6) competitive, market-driven private sector involvement in land remote sensing is in the national interest of the United States;

(7) use of land remote-sensing data has been inhibited by slow market development and by the lack of assurance of data continuity;

(8) the private sector, and in particular the "value-added" industry, is best suited to develop land remote-sensing data markets;

(9) there is doubt that the private sector alone can currently develop a total land remote-sensing system because of the high risk and large capital expenditure involved;

(10) cooperation between the Federal Government and private industry can help assure both data continuity and United States leadership;

(11) the time is now appropriate to initiate such cooperation with phased transition to a fully commercial system;

(12) such cooperation should be structured to involve the minimum practicable amount of support and regulation by the

Federal Government and the maximum practicable amount of competition by the private sector, while assuring continuous availability to the Federal Government of land remote-sensing data;

(13) certain Government oversight must be maintained to assure that private sector activities are in the national interest and that the international commitments and policies of the United States are honored; and

(14) there is no compelling reason to commercialize meteorological satellites at this time.

PURPOSES

15 USC 4202.

SEC. 102. The purposes of this Act are to—

(1) guide the Federal Government in achieving proper involvement of the private sector by providing a framework for phased commercialization of land remote sensing and by assuring continuous data availability to the Federal Government;

Defense and national security.

(2) maintain the United States worldwide leadership in civil remote sensing, preserve its national security, and fulfill its international obligations;

(3) minimize the duration and amount of further Federal investment necessary to assure data continuity while achieving commercialization of civil land remote sensing;

(4) provide for a comprehensive civilian program of research, development, and demonstration to enhance both the United States capabilities for remote sensing from space and the application and utilization of such capabilities; and

(5) prohibit commercialization of meteorological satellites at this time.

POLICIES

15 USC 4203.

SEC. 103. (a) It shall be the policy of the United States to preserve its right to acquire and disseminate unenhanced remote-sensing data.

(b) It shall be the policy of the United States that civilian unenhanced remote-sensing data be made available to all potential users on a nondiscriminatory basis and in a manner consistent with applicable antitrust laws.

Defense and national security.

(c) It shall be the policy of the United States both to commercialize those remote-sensing space systems that properly lend themselves to private sector operation and to avoid competition by the Government with such commercial operations, while continuing to preserve our national security, to honor our international obligations, and to retain in the Government those remote-sensing functions that are essentially of a public service nature.

DEFINITIONS

15 USC 4204.

SEC. 104. For purposes of this Act:

(1) The term "Landsat system" means Landsats 1, 2, 3, 4, and 5, and any related ground equipment, systems, and facilities, and any successor civil land remote-sensing space systems operated by the United States Government prior to the commencement of the six-year period described in title III.

(2) The term "Secretary" means the Secretary of Commerce.

(3)(A) The term "nondiscriminatory basis" means without preference, bias, or any other special arrangement (except on the basis of national security concerns pursuant to section 607) regarding delivery, format, financing, or technical considerations which would favor one buyer or class of buyers over another.

(B) The sale of data is made on a nondiscriminatory basis only if (i) any offer to sell or deliver data is published in advance in such manner as will ensure that the offer is equally available to all prospective buyers; (ii) the system operator has not established or changed any price, policy, procedure, or other term or condition in a manner which gives one buyer or class of buyer de facto favored access to data; (iii) the system operator does not make unenhanced data available to any purchaser on an exclusive basis; and (iv) in a case where a system operator offers volume discounts, such discounts are no greater than the demonstrable reductions in the cost of volume sales. The sale of data on a nondiscriminatory basis does not preclude the system operator from offering discounts other than volume discounts to the extent that such discounts are consistent with the provisions of this paragraph.

(C) The sale of data on a nondiscriminatory basis does not require (i) that a system operator disclose names of buyers or their purchases; (ii) that a system operator maintain all, or any particular subset of, data in a working inventory; or (iii) that a system operator expend equal effort in developing all segments of a market.

(4) The term "unenhanced data" means unprocessed or minimally processed signals or film products collected from civil remote-sensing space systems. Such minimal processing may include rectification of distortions, registration with respect to features of the Earth, and calibration of spectral response. Such minimal processing does not include conclusions, manipulations, or calculations derived from such signals or film products or combination of the signals or film products with other data or information.

(5) The term "system operator" means a contractor under title II or title III or a license holder under title IV.

TITLE II—OPERATION AND DATA MARKETING OF LANDSAT SYSTEM

OPERATION

SEC. 201. (a) The Secretary shall be responsible for— 15 USC 4211.

(1) the Landsat system, including the orbit, operation, and disposition of Landsats 1, 2, 3, 4, and 5; and

(2) provision of data to foreign ground stations under the terms of agreements between the United States Government and nations that operate such ground stations which are in force on the date of commencement of the contract awarded pursuant to this title.

(b) The provisions of this section shall not affect the Secretary's authority to contract for the operation of part or all of the Landsat system, so long as the United States Government retains—

(1) ownership of such system;

(2) ownership of the unenhanced data; and

(3) authority to make decisions concerning operation of the system.

CONTRACT FOR MARKETING OF UNENHANCED DATA

15 USC 4212.

SEC. 202. (a) In accordance with the requirements of this title, the Secretary, by means of a competitive process and to the extent provided in advance by appropriation Acts, shall contract with a United States private sector party (as defined by the Secretary) for the marketing of unenhanced data collected by the Landsat system. Any such contract—

(1) shall provide that the contractor set the prices of unenhanced data;

(2) may provide for financial arrangements between the Secretary and the contractor including fees for operating the system, payments by the contractor as an initial fee or as a percentage of sales receipts, or other such considerations;

(3) shall provide that the contractor will offer to sell and deliver unenhanced data to all potential buyers on a nondiscriminatory basis;

(4) shall provide that the contractor pay to the United States Government the full purchase price of any unenhanced data that the contractor elects to utilize for purposes other than sale;

(5) shall be entered into by the Secretary only if the Secretary has determined that such contract is likely to result in net cost savings for the United States Government; and

(6) may be reawarded competitively after the practical demise of the space segment of the Landsat system, as determined by the Secretary.

(b) Any contract authorized by subsection (a) may specify that the contractor use, and, at his own expense, maintain, repair, or modify, such elements of the Landsat system as the contractor finds necessary for commercial operations.

Congress.

(c) Any decision or proposed decision by the Secretary to enter into any such contract shall be transmitted to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Science and Technology of the House of Representatives for their review. No such decision or proposed decision shall be implemented unless (A) a period of thirty calendar days has passed after the receipt by each such committee of such transmittal, or (B) each such committee before the expiration of such period has agreed to transmit and has transmitted to the Secretary written notice to the effect that such committee has no objection to the decision or proposed decision. As part of the transmittal, the Secretary shall include information on the terms of the contract described in subsection (a).

(d) In defining "United States private sector party" for purposes of this Act, the Secretary may take into account the citizenship of key personnel, location of assets, foreign ownership, control, influence, and other such factors.

CONDITIONS OF COMPETITION FOR CONTRACT

15 USC 4213.

SEC. 203. (a) The Secretary shall, as part of the advertisement for the competition for the contract authorized by section 202, identify and publish the international obligations, national security concerns (with appropriate protection of sensitive information), domestic legal considerations, and any other standards or conditions which a private contractor shall be required to meet.

(b) In selecting a contractor under this title, the Secretary shall consider—

(1) ability to market aggressively unenhanced data;

(2) the best overall financial return to the Government, including the potential cost savings to the Government that are likely to result from the contract;

(3) ability to meet the obligations, concerns, considerations, standards, and conditions identified under subsection (a);

(4) technical competence, including the ability to assure continuous and timely delivery of data from the Landsat system;

(5) ability to effect a smooth transition with the contractor selected under title III; and

(6) such other factors as the Secretary deems appropriate and relevant.

(c) If, as a result of the competitive process required by section 202(a), the Secretary receives no proposal which is acceptable under the provisions of this title, the Secretary shall so certify and fully report such finding to the Congress. As soon as practicable but not later than thirty days after so certifying and reporting, the Secretary shall reopen the competitive process. The period for the subsequent competitive process shall not exceed one hundred and twenty days. If, after such subsequent competitive process, the Secretary receives no proposal which is acceptable under the provisions of this title, the Secretary shall so certify and fully report such finding to the Congress. In the event that no acceptable proposal is received, the Secretary shall continue to market data from the Landsat system. Report.

(d) A contract awarded under section 202 may, in the discretion of the Secretary, be combined with the contract required by title III, pursuant to section 304(b).

SALE OF DATA

Sec. 204. (a) After the date of the commencement of the contract described in section 202(a), the contractor shall be entitled to revenues from sales of copies of data from the Landsat system, subject to the conditions specified in sections 601 and 602. 15 USC 4214.

(b) The contractor may continue to market data previously generated by the Landsat system after the demise of the space segment of that system.

FOREIGN GROUND STATIONS

Sec. 205. (a) The contract under this title shall provide that the contractor shall act as the agent of the Secretary by continuing to supply unenhanced data to foreign ground stations for the life, and according to the terms, of those agreements between the United States Government and such foreign ground stations that are in force on the date of the commencement of the contract. 15 USC 4215.

(b) Upon the expiration of such agreements, or in the case of foreign ground stations that have no agreement with the United States on the date of commencement of the contract, the contract shall provide—

(1) that unenhanced data from the Landsat system shall be made available to foreign ground stations only by the contractor; and

(2) that such data shall be made available on a nondiscriminatory basis.

TITLE III—PROVISION OF DATA CONTINUITY AFTER THE LANDSAT SYSTEM

PURPOSES AND DEFINITION

15 USC 4221.

SEC. 301. (a) It is the purpose of this title—

(1) to provide, in an orderly manner and with minimal risk, for a transition from Government operation to private, commercial operation of civil land remote-sensing systems; and

(2) to provide data continuity for six years after the practical demise of the space segment of the Landsat system.

(b) For purposes of this title, the term "data continuity" means the continued availability of unenhanced data—

(1) including data which are from the point of view of a data user—

(A) functionally equivalent to the multispectral data generated by the Landsat 1 and 2 satellites; and

(B) compatible with such data and with equipment used to receive and process such data; and

(2) at an annual volume at least equal to the Federal usage during fiscal year 1983.

(c) Data continuity may be provided using whatever technologies are available.

DATA CONTINUITY AND AVAILABILITY

Contracts with U.S.
15 USC 4222.

SEC. 302. The Secretary shall solicit proposals from United States private sector parties (as defined by the Secretary pursuant to section 202) for a contract for the development and operation of a remote-sensing space system capable of providing data continuity for a period of six years and for marketing unenhanced data in accordance with the provisions of sections 601 and 602. Such proposals, at a minimum, shall specify—

(1) the quantities and qualities of unenhanced data expected from the system;

(2) the projected date upon which operations could begin;

(3) the number of satellites to be constructed and their expected lifetimes;

(4) any need for Federal funding to develop the system;

(5) any percentage of sales receipts or other returns offered to the Federal Government;

(6) plans for expanding the market for land remote-sensing data; and

(7) the proposed procedures for meeting the national security concerns and international obligations of the United States in accordance with section 607.

AWARDING OF THE CONTRACT

15 USC 4223.

SEC. 303. (a)(1) In accordance with the requirements of this title, the Secretary shall evaluate the proposals described in section 302 and, by means of a competitive process and to the extent provided in advance by appropriation Acts, shall contract with the United States private sector party for the capability of providing data continuity for a period of six years and for marketing unenhanced data.

(2) Before commencing space operations the contractor shall obtain a license under title IV.

(b) As part of the evaluation described in subsection (a), the Secretary shall analyze the expected outcome of each proposal in terms of—

(1) the net cost to the Federal Government of developing the recommended system;

(2) the technical competence and financial condition of the contractor;

(3) the availability of such data after the expected termination of the Landsat system;

(4) the quantities and qualities of data to be generated by the recommended system;

(5) the contractor's ability to supplement the requirement for data continuity by adding, at the contractor's expense, remote-sensing capabilities which maintain United States leadership in remote sensing;

(6) the potential to expand the market for data;

(7) expected returns to the Federal Government based on any percentage of data sales or other such financial consideration offered to the Federal Government in accordance with section 305;

(8) the commercial viability of the proposal;

(9) the proposed procedures for satisfying the national security concerns and international obligations of the United States;

(10) the contractor's ability to effect a smooth transition with any contractor selected under title II; and

(11) such other factors as the Secretary deems appropriate and relevant.

Congress.

(c) Any decision or proposed decision by the Secretary to enter into any such contract shall be transmitted to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Science and Technology of the House of Representatives for their review. No such decision or proposed decision shall be implemented unless (1) a period of thirty calendar days has passed after the receipt by each such committee of such transmittal, or (2) each such committee before the expiration of such period has agreed to transmit and has transmitted to the Secretary written notice to the effect that such committee has no objection to the decision or proposed decision. As part of the transmittal, the Secretary shall include the information specified in subsection (a).

Report.

(d) If, as a result of the competitive process required by this section, the Secretary receives no proposal which is acceptable under the provisions of this title, the Secretary shall so certify and fully report such finding to the Congress. As soon as practicable but not later than thirty days after so certifying and reporting, the Secretary shall reopen the competitive process. The period for the subsequent competitive process shall not exceed one hundred and eighty days. If, after such subsequent competitive process, the Secretary receives no proposal which is acceptable under the provisions of this title, the Secretary shall so certify and fully report such finding to the Congress. Not earlier than ninety days after such certification and report, the Secretary may assure data continuity by procurement and operation by the Federal Government of the necessary systems, to the extent provided in advance by appropriation Acts.

TERMS OF CONTRACT

15 USC 4224.

Sec. 304. (a) Any contract entered into pursuant to this title—

(1) shall be entered into as soon as practicable, allowing for the competitive procurement process required by this title;

(2) shall, in accordance with criteria determined and published by the Secretary, reasonably assure data continuity for a period of six years, beginning as soon as practicable in order to minimize any interruption of data availability;

(3) shall provide that the contractor will offer to sell and deliver unenhanced data to all potential buyers on a nondiscriminatory basis;

(4) shall not provide a guarantee of data purchases from the contractor by the Federal Government;

(5) may provide that the contractor utilize, on a space-available basis, a civilian United States Government satellite or vehicle as a platform for a civil land remote-sensing space system, if—

(A) the contractor agrees to reimburse the Government immediately for all related costs incurred with respect to such utilization, including a reasonable and proportionate share of fixed, platform, data transmission, and launch costs; and

(B) such utilization would not interfere with or otherwise compromise intended civilian Government missions, as determined by the agency responsible for the civilian platform; and

(6) may provide financial support by the United States Government, for a portion of the capital costs required to provide data continuity for a period of six years, in the form of loans, loan guarantees, or payments pursuant to section 305 of the Federal Property and Administrative Services Act of 1949 (41 U.S.C. 255).

(b)(1) Without regard to whether any contract entered into under this title is combined with a contract under title II, the Secretary shall promptly determine whether the contract entered into under this title reasonably effectuates the purposes and policies of title II. Such determination shall be submitted to the President and the Congress, together with a full statement of the basis for such determination.

(2) If the Secretary determines that such contract does not reasonably effectuate the requirements of title II, the Secretary shall promptly carry out the provisions of such title to the extent provided in advance in appropriations Acts.

MARKETING

15 USC 4225.

Sec. 305. (a) In order to promote aggressive marketing of land remote-sensing data, any contract entered into pursuant to this title may provide that the percentage of sales paid by the contractor to the Federal Government shall decrease according to stipulated increases in sales levels.

(b) After the six-year period described in section 304(a)(2), the contractor may continue to sell data. If licensed under title IV, the contractor may continue to operate a civil remote-sensing space system.

REPORT

15 USC 4226.

SEC. 306. Two years after the date of the commencement of the six-year period described in section 304(a)(2), the Secretary shall report to the President and to the Congress on the progress of the transition to fully private financing, ownership, and operation of remote-sensing space systems, together with any recommendations for actions, including actions necessary to ensure United States leadership in civilian land remote sensing from space.

TERMINATION OF AUTHORITY

15 USC 4227.

SEC. 307. The authority granted to the Secretary by this title shall terminate ten years after the date of enactment of this Act.

TITLE IV—LICENSING OF PRIVATE REMOTE-SENSING SPACE SYSTEMS

GENERAL AUTHORITY

15 USC 4241.

SEC. 401. (a)(1) In consultation with other appropriate Federal agencies, the Secretary is authorized to license private sector parties to operate private remote-sensing space systems for such period as the Secretary may specify and in accordance with the provisions of this title.

(2) In the case of a private space system that is used for remote sensing and other purposes, the authority of the Secretary under this title shall be limited only to the remote-sensing operations of such space system.

(b) No license shall be granted by the Secretary unless the Secretary determines in writing that the applicant will comply with the requirements of this Act, any regulations issued pursuant to this Act, and any applicable international obligations and national security concerns of the United States.

Review date.

(c) The Secretary shall review any application and make a determination thereon within one hundred and twenty days of the receipt of such application. If final action has not occurred within such time, the Secretary shall inform the applicant of any pending issues and of actions required to resolve them.

(d) The Secretary shall not deny such license in order to protect any existing licensee from competition.

CONDITIONS FOR OPERATION

15 USC 4242.

SEC. 402. (a) No person who is subject to the jurisdiction or control of the United States may, directly or through any subsidiary or affiliate, operate any private remote-sensing space system without a license pursuant to section 401.

(b) Any license issued pursuant to this title shall specify, at a minimum, that the licensee shall comply with all of the requirements of this Act and shall—

Defense and national security.

(1) operate the system in such manner as to preserve and promote the national security of the United States and to observe and implement the international obligations of the United States in accordance with section 607;

(2) make unenhanced data available to all potential users on a nondiscriminatory basis;

(3) upon termination of operations under the license, make disposition of any satellites in space in a manner satisfactory to the President;

(4) promptly make available all unenhanced data which the Secretary may request pursuant to section 602;

(5) furnish the Secretary with complete orbit and data collection characteristics of the system, obtain advance approval of any intended deviation from such characteristics, and inform the Secretary immediately of any unintended deviation;

(6) notify the Secretary of any agreement the licensee intends to enter with a foreign nation, entity, or consortium involving foreign nations or entities;

(7) permit the inspection by the Secretary of the licensee's equipment, facilities, and financial records;

(8) surrender the license and terminate operations upon notification by the Secretary pursuant to section 403(a)(1); and

(9)(A) notify the Secretary of any "value added" activities (as defined by the Secretary by regulation) that will be conducted by the licensee or by a subsidiary or affiliate; and

(B) if such activities are to be conducted, provide the Secretary with a plan for compliance with the provisions of this Act concerning nondiscriminatory access.

ADMINISTRATIVE AUTHORITY OF THE SECRETARY

15 USC 4243.

SEC. 403. (a) In order to carry out the responsibilities specified in this title, the Secretary may—

(1) grant, terminate, modify, condition, transfer, or suspend licenses under this title, and upon notification of the licensee may terminate licensed operations on an immediate basis, if the Secretary determines that the licensee has substantially failed to comply with any provision of this Act, with any regulation issued under this Act, with any terms, conditions, or restrictions of such license, or with any international obligations or national security concerns of the United States;

(2) inspect the equipment, facilities, or financial records of any licensee under this title;

(3) provide penalties for noncompliance with the requirements of licenses or regulations issued under this title, including civil penalties not to exceed $10,000 (each day of operation in violation of such licenses or regulations constituting a separate violation);

(4) compromise, modify, or remit any such civil penalty;

(5) issue subpenas for any materials, documents, or records, or for the attendance and testimony of witnesses for the purpose of conducting a hearing under this section;

(6) seize any object, record, or report where there is probable cause to believe that such object, record, or report was used, is being used, or is likely to be used in violation of this Act or the requirements of a license or regulation issued thereunder; and

(7) make investigations and inquiries and administer to or take from any person an oath, affirmation, or affidavit concerning any matter relating to the enforcement of this Act.

(b) Any applicant or licensee who makes a timely request for review of an adverse action pursuant to subsection (a)(1), (a)(3), or (a)(6) shall be entitled to adjudication by the Secretary on the record after an opportunity for an agency hearing with respect to such adverse action. Any final action by the Secretary under this subsection shall be subject to judicial review under chapter 7 of title 5, United States Code. 5 USC 701 *et seq.*

REGULATORY AUTHORITY OF THE SECRETARY

SEC. 404. The Secretary may issue regulations to carry out the provisions of this title. Such regulations shall be promulgated only after public notice and comment in accordance with the provisions of section 553 of title 5, United States Code. 15 USC 4244.

AGENCY ACTIVITIES

SEC. 405. (a) A private sector party may apply for a license to operate a private remote-sensing space system which utilizes, on a space-available basis, a civilian United States Government satellite or vehicle as a platform for such system. The Secretary, pursuant to the authorities of this title, may license such system if it meets all conditions of this title and— 15 USC 4245.

(1) the system operator agrees to reimburse the Government immediately for all related costs incurred with respect to such utilization, including a reasonable and proportionate share of fixed, platform, data transmission, and launch costs; and

(2) such utilization would not interfere with or otherwise compromise intended civilian Government missions, as determined by the agency responsible for such civilian platform.

(b) The Secretary may offer assistance to private sector parties in finding appropriate opportunities for such utilization.

(c) To the extent provided in advance by appropriation Acts, any Federal agency may enter into agreements for such utilization if such agreements are consistent with such agency's mission and statutory authority, and if such remote-sensing space system is licensed by the Secretary before commencing operation.

(d) The provisions of this section do not apply to activities carried out under title V.

(e) Nothing in this title shall affect the authority of the Federal Communications Commission pursuant to the Communications Act of 1934, as amended (47 U.S.C. 151 et seq.). 47 USC 609.

TERMINATION

SEC. 406. If, five years after the expiration of the six-year period described in section 304(a)(2), no private sector party has been licensed and continued in operation under the provisions of this title, the authority of this title shall terminate. 15 USC 4246.

TITLE V—RESEARCH AND DEVELOPMENT

CONTINUED FEDERAL RESEARCH AND DEVELOPMENT

SEC. 501. (a)(1) The Administrator of the National Aeronautics and Space Administration is directed to continue and to enhance such Administration's programs of remote-sensing research and development. 15 USC 4261.

(2) The Administrator is authorized and encouraged to—

(A) conduct experimental space remote-sensing programs (including applications demonstration programs and basic research at universities);

(B) develop remote-sensing technologies and techniques, including those needed for monitoring the Earth and its environment; and

(C) conduct such research and development in cooperation with other Federal agencies and with public and private research entities (including private industry, universities, State and local governments, foreign governments, and international organizations) and to enter into arrangements (including joint ventures) which will foster such cooperation.

(b)(1) The Secretary is directed to conduct a continuing program of—

(A) research in applications of remote-sensing;

(B) monitoring of the Earth and its environment; and

(C) development of technology for such monitoring.

(2) Such program may include support of basic research at universities and demonstrations of applications.

(3) The Secretary is authorized and encouraged to conduct such research, monitoring, and development in cooperation with other Federal agencies and with public and private research entities (including private industry, universities, State and local governments, foreign governments, and international organizations) and to enter into arrangements (including joint ventures) which will foster such cooperation.

(c)(1) In order to enhance the United States ability to manage and utilize its renewable and nonrenewable resources, the Secretary of Agriculture and the Secretary of the Interior are authorized and encouraged to conduct programs of research and development in the applications of remote sensing using funds appropriated for such purposes.

(2) Such programs may include basic research at universities, demonstrations of applications, and cooperative activities involving other Government agencies, private sector parties, and foreign and international organizations.

(d) Other Federal agencies are authorized and encouraged to conduct research and development on the use of remote sensing in fulfillment of their authorized missions, using funds appropriated for such purposes.

Report.

(e) The Secretary and the Administrator of the National Aeronautics and Space Administration shall, within one year after the date of enactment of this Act and biennially thereafter, jointly develop and transmit to the Congress a report which includes (1) a unified national plan for remote-sensing research and development applied to the Earth and its atmosphere; (2) a compilation of progress in the relevant ongoing research and development activities of the Federal agencies; and (3) an assessment of the state of our knowledge of the Earth and its atmosphere, the needs for additional research (including research related to operational Federal remote-sensing space programs), and opportunities available for further progress.

USE OF EXPERIMENTAL DATA

15 USC 4262.

SEC. 502. Data gathered in Federal experimental remote-sensing space programs may be used in related research and development programs funded by the Federal Government (including applications programs) and cooperative research programs, but not for commercial uses or in competition with private sector activities, except pursuant to section 503.

SALE OF EXPERIMENTAL DATA

15 USC 4263.

SEC. 503. Data gathered in Federal experimental remote-sensing space programs may be sold en bloc through a competitive process (consistent with national security interests and international obligations of the United States and in accordance with section 607) to any United States entity which will market the data on a nondiscriminatory basis.

TITLE VI—GENERAL PROVISIONS

NONDISCRIMINATORY DATA AVAILABILITY

Public availability.
15 USC 4271.

SEC. 601. (a) Any unenhanced data generated by any system operator under the provisions of this Act shall be made available to all users on a nondiscriminatory basis in accordance with the requirements of this Act.

(b) Any system operator shall make publicly available the prices, policies, procedures, and other terms and conditions (but, in accordance with section 104(3)(C), not necessarily the names of buyers or their purchases) upon which the operator will sell such data.

ARCHIVING OF DATA

15 USC 4272.

SEC. 602. (a) It is in the public interest for the United States Government—

(1) to maintain an archive of land remote-sensing data for historical, scientific, and technical purposes, including long-term global environmental monitoring;

(2) to control the content and scope of the archive; and

(3) to assure the quality, integrity, and continuity of the archive.

(b) The Secretary shall provide for long-term storage, maintenance, and upgrading of a basic, global, land remote-sensing data set (hereinafter referred to as the "basic data set") and shall follow reasonable archival practices to assure proper storage and preservation of the basic data set and timely access for parties requesting data. The basic data set which the Secretary assembles in the Government archive shall remain distinct from any inventory of data which a system operator may maintain for sales and for other purposes.

(c) In determining the initial content of, or in upgrading, the basic data set, the Secretary shall—

(1) use as a baseline the data archived on the date of enactment of this Act;

(2) take into account future technical and scientific developments and needs;

(3) consult with and seek the advice of users and producers of remote-sensing data and data products;

(4) consider the need for data which may be duplicative in terms of geographical coverage but which differ in terms of season, spectral bands, resolution, or other relevant factors;

(5) include, as the Secretary considers appropriate, unenhanced data generated either by the Landsat system, pursuant to title III, or by licensees under title IV;

(6) include, as the Secretary considers appropriate, data collected by foreign ground stations or by foreign remote-sensing space systems; and

(7) ensure that the content of the archive is developed in accordance with section 607.

(d) Subject to the availability of appropriations, the Secretary shall request data needed for the basic data set and pay to the providing system operator reasonable costs for reproduction and transmission. A system operator shall promptly make requested data available in a form suitable for processing for archiving.

Marketing. (e) Any system operator shall have the exclusive right to sell all data that the operator provides to the United States remote-sensing data archive for a period to be determined by the Secretary but not to exceed ten years from the date the data are sensed. In the case of data generated from the Landsat system prior to the implementation of the contract described in section 202(a), any contractor selected pursuant to section 202 shall have the exclusive right to market such data on behalf of the United States Government for the duration of such contract. A system operator may relinquish the exclusive right and consent to distribution from the archive before the period of exclusive right has expired by terminating the offer to sell particular data.

Public availability. (f) After the expiration of such exclusive right to sell, or after relinquishment of such right, the data provided to the United States remote-sensing data archive shall be in the public domain and shall be made available to requesting parties by the Secretary at prices reflecting reasonable costs of reproduction and transmittal.

(g) In carrying out the functions of this section, the Secretary shall, to the extent practicable and as provided in advance by appropriation Acts, use existing Government facilities.

NONREPRODUCTION

15 USC 4273. SEC. 603. Unenhanced data distributed by any system operator under the provisions of this Act may be sold on the condition that such data will not be reproduced or disseminated by the purchaser.

REIMBURSEMENT FOR ASSISTANCE

15 USC 4274. SEC. 604. The Administrator of the National Aeronautics and Space Administration, the Secretary of Defense and the heads of other Federal agencies may provide assistance to system operators under the provisions of this Act. Substantial assistance shall be reimbursed by the operator, except as otherwise provided by law.

ACQUISITION OF EQUIPMENT

15 USC 4275. SEC. 605. The Secretary may, by means of a competitive process, allow a licensee under title IV or any other private party to buy, lease, or otherwise acquire the use of equipment from the Landsat system, when such equipment is no longer needed for the operation of such system or for the sale of data from such system. Officials of other Federal civilian agencies are authorized and encouraged to cooperate with the Secretary in carrying out the provisions of this section.

RADIO FREQUENCY ALLOCATION

President of U.S.
15 USC 4276.

SEC. 606. (a) Within thirty days after the date of enactment of this Act, the President (or the President's delegee, if any, with authority over the assignment of frequencies to radio stations or classes of radio stations operated by the United States) shall make available for nongovernmental use spectrum presently allocated to Government use, for use by United States Landsat and commercial remote-sensing space systems. The spectrum to be so made available shall conform to any applicable international radio or wire treaty or convention, or regulations annexed thereto. Within ninety days thereafter, the Federal Communications Commission shall utilize appropriate procedures to authorize the use of such spectrum for nongovernmental use. Nothing in this section shall preclude the ability of the Commission to allocate additional spectrum to commercial land remote-sensing space satellite system use.

(b) To the extent required by the Communications Act of 1934, as amended (47 U.S.C. 151 et seq.), an application shall be filed with the Federal Communications Commission for any radio facilities involved with the commercial remote-sensing space system. 47 USC 609.

(c) It is the intent of Congress that the Federal Communications Commission complete the radio licensing process under the Communications Act of 1934, as amended (47 U.S.C. 151 et seq.), upon the application of any private sector party or consortium operator of any commercial land remote-sensing space system subject to this Act, within one hundred and twenty days of the receipt of an application for such licensing. If final action has not occurred within one hundred and twenty days of the receipt of such an application, the Federal Communications Commission shall inform the applicant of any pending issues and of actions required to resolve them.

(d) Authority shall not be required from the Federal Communications Commission for the development and construction of any United States land remote-sensing space system (or component thereof), other than radio transmitting facilities or components, while any licensing determination is being made.

(e) Frequency allocations made pursuant to this section by the Federal Communications Commission shall be consistent with international obligations and with the public interest.

CONSULTATION

Defense and national security.
15 USC 4277.

SEC. 607. (a) The Secretary shall consult with the Secretary of Defense on all matters under this Act affecting national security. The Secretary of Defense shall be responsible for determining those conditions, consistent with this Act, necessary to meet national security concerns of the United States and for notifying the Secretary promptly of such conditions.

(b)(1) The Secretary shall consult with the Secretary of State on all matters under this Act affecting international obligations. The Secretary of State shall be responsible for determining those conditions, consistent with this Act, necessary to meet international obligations and policies of the United States and for notifying the Secretary promptly of such conditions.

(2) Appropriate Federal agencies are authorized and encouraged to provide remote-sensing data, technology, and training to developing nations as a component of programs of international aid.

(3) The Secretary of State shall promptly report to the Secretary any instances outside the United States of discriminatory distribution of data.

(c) If, as a result of technical modifications imposed on a system operator on the basis of national security concerns, the Secretary, in consultation with the Secretary of Defense or with other Federal agencies, determines that additional costs will be incurred by the system operator, or that past development costs (including the cost of capital) will not be recovered by the system operator, the Secretary may require the agency or agencies requesting such technical modifications to reimburse the system operator for such additional or development costs, but not for anticipated profits. Reimbursements may cover costs associated with required changes in system performance, but not costs ordinarily associated with doing business abroad.

AMENDMENT TO NATIONAL AERONAUTICS AND SPACE ADMINISTRATION AUTHORIZATION, 1983

15 USC 1517 note.

SEC. 608. Subsection (a) of section 201 of the National Aeronautics and Space Administration Authorization Act, 1983 (Public Law 97-324; 96 Stat. 1601) is amended to read as follows:

"(a) The Secretary of Commerce is authorized to plan and provide for the management and operation of civil remote-sensing space systems, which may include the Landsat 4 and 5 satellites and associated ground system equipment transferred from the National Aeronautics and Space Administration; to provide for user fees; and to plan for the transfer of the operation of civil remote-sensing space systems to the private sector when in the national interest.".

AUTHORIZATION OF APPROPRIATIONS

15 USC 4278.

SEC. 609. (a) There are authorized to be appropriated to the Secretary $75,000,000 for fiscal year 1985 for the purpose of carrying out the provisions of this Act. Such sums shall remain available until expended, but shall not become available until the time periods specified in sections 202(c) and 303(c) have expired.

(b) The authorization provided for under subsection (a) shall be in addition to moneys authorized pursuant to title II of the National Aeronautics and Space Administration Authorization Act, 1983.

15 USC 1517 note.

TITLE VII—PROHIBITION OF COMMERCIALIZATION OF WEATHER SATELLITES

PROHIBITION

President of U.S.
15 USC 4291.

SEC. 701. Neither the President nor any other official of the Government shall make any effort to lease, sell, or transfer to the private sector, commercialize, or in any way dismantle any portion of the weather satellite systems operated by the Department of Commerce or any successor agency.

FUTURE CONSIDERATIONS

Sec. 702. Regardless of any change in circumstances subsequent to the enactment of this Act, even if such change makes it appear to be in the national interest to commercialize weather satellites, neither the President nor any official shall take any action prohibited by section 701 unless this title has first been repealed. 15 USC 4292.

Approved July 17, 1984.

LEGISLATIVE HISTORY—H.R. 5155:

HOUSE REPORT No. 98-647 (Comm. on Science and Technology).
SENATE REPORT No. 98-458 (Comm. on Commerce, Science, and Transportation).
CONGRESSIONAL RECORD, Vol. 130 (1984):
    Apr. 9, considered and passed House.
    June 8, considered and passed Senate, amended.
    June 28, House concurred in Senate amendment with an amendment.
    June 29, Senate concurred in House amendment.
WEEKLY COMPILATION OF PRESIDENTIAL DOCUMENTS, Vol. 20, No. 29 (1984):
    July 17, Presidential statement.

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APPENDIX F-4

White House Fact Sheet
National Space Strategy (August 15, 1984)

FACT SHEET

NATIONAL SPACE STRATEGY

Introduction

On August 15, 1984, the President approved a National Space Strategy designed to implement the National Space Policy, as supplemented by the President's 1984 State of the Union Address. The strategy identifies selected, high priority efforts and responsibilities, and provides implementation plans for major space policy objectives. This strategy is consistent with other space-related National Security Decision Directives and other Administration policies. A summary of the strategy's contents is provided below.

The Space Transportation System (STS)

Insure routine, cost-effective access to space with the STS. The STS is a critical factor in maintaining U.S. space leadership, in accomplishing the basic goals of the National Space Policy, and in achieving a permanent manned presence in space. It is the primary space launch system for both national security and civil government missions. As such, NASA's first priority is to make the STS fully operational and cost-effective in providing routine access to space.

Implementation: The STS program will receive sustained commitments by all affected departments and agencies. Enhancements of STS operational capability, upper stages, and efficient methods of deploying and retrieving payloads will be pursued as national requirements are defined.

NASA and Department of Defense will jointly prepare a report that defines a fully operational and cost-effective STS and specifies the steps leading to that status. This will be prepared and submitted for review by the Senior Interagency Group for Space—SIG(Space)—no later than November 30, 1984.

The STS will be fully operational by 1988. On October 1, 1988, prices for STS services and capabilities provided to commercial and foreign users will reflect the full cost of such services and capabilities. NASA will develop a time-phased plan for implementing full cost recovery for commercial and foreign STS flight operations. At a minimum, this plan will include an option for full cost recovery for commercial and foreign flights which occur after October 1, 1988. OMB, in consultation with DOC, DOT, DOD, NASA and other agencies will prepare a joint assessment of the ability of the U.S. private sector and the STS to maintain international competitiveness in the provision of launch services. This analysis should include an assessment of all factors relevant to foreign ELVs, U.S. ELVs and the STS. NASA will keep OMB fully apprised of the elements of its time-phased plan as it is being developed. Both the time-phased plan and the OMB analysis will be submitted for review and comment by the SIG(Space) and the Cabinet Council on Commerce and Trade no later than September 15, 1984, and subsequently submitted for the President's approval in order to permit their consideration in the development of the FY 1986 budget.

The Department of Defense and NASA will jointly conduct a study to identify launch vehicle technology that could be made available for use in the post-1995 period. The study should be completed by December 31, 1984.

The Civil Space Program

Establish a permanently manned presence in space. NASA will develop a permanently manned Space Station within a decade. The development of a civil Space Station will further the goals of space leadership and the peaceful exploration and use of space for the benefit of all mankind. The Space Station will enhance the development of the commercial potential of space. It will facilitate scientific research in space. It will also, in the longer term, serve as a basis for future major civil and commercial activities to explore and exploit space.

Implementation: As a civil program, the Space Station will be funded and executed by NASA beginning in FY 1985 with the goal of the establishment of a permanently manned presence in space within a decade.

Foster increased international cooperation in civil space activities. The U.S. will seek mutually beneficial international participation in its civil and commercial space and space-related programs. As a centerpiece of this priority, the U.S. will seek agreements with friends and allies to participate in the development and utilization of the Space Station.

Implementation: NASA and the Department of State will make every effort to obtain maximum mutually beneficial foreign participation in the Space Station program, consistent with the Presidential commitment for international participation and other guidance. The broad objectives of the United States in international cooperation in space activities are to promote foreign policy considerations, advance national science and technology; maximize national economic benefits, including domestic considerations; and protect national security. The suitability of each cooperative space activity must be judged within the framework of all these objectives. Consistent with these objectives, the SIG(Space) will review all major policy issues raised by proposed agreements for international participation on the Space Station program prior to commitments by the U.S. Government.

Identify major long-range national goals for the civil space program. Major long-range goals for the civil space program are essential to meeting the national commitment to maintain United States leadership in space and to exploit space for economic and scientific benefit.

Implementation: In accordance with the FY 1985 NASA Authorization Act, the President will appoint a National Commission on Space to formulate an agenda for the United States space program. The Commission shall identify goals, opportunities, and policy options for United States civilian space activity for the next twenty years. Upon submission of the Commission report to the President, the Office of Science and Technology Policy, in cooperation with NASA and other appropriate agencies, will review the report and will provide their comments and recommendations to the President through the SIG(Space) within 60 days of the submission of the Commission report.

Insure a vigorous and balanced program of civil scientific research and exploration in space. The U.S. civil space science program is an essential element of U.S. leadership in space, a vehicle for scientific advancement and long-term economic benefits, and a valuable opportunity for international cooperation.

Implementation: NASA and other appropriate agencies will conduct their activities in a manner that will maintain a vigorous and balanced program of civil space research and exploration. NASA will explicitly factor the broad spectrum of capabilities necessary for space science into the planning and development of the manned Space Station and will implement those plans in a manner that will lend stability and continuity to research in the space sciences. Furthermore, the Office of Science and Technology Policy, in conjunction with NASA and other appropriate agencies, will review and define the goals and missions of the various civil agencies in the area of earth sciences research and will provide their recommendations in a report to the SIG(Space) by April 1, 1985.

Commercial Space Program

Encourage commercial Expendable Launch Vehicle activities. The U.S. will encourage and faciliate commercial expendable launch vehicle operations. U.S. Government policies will promote competitive opportunities for commercial expendable launch vehicle operations and minimize government regulation of these activities.

Implementation: The Department of Transportation will carry out the responsibilities assigned by Executive Order 12465 on Commercial Expendable Launch Vehicle Activities. Appropriate agencies will work with Department of Transportation to encourage the U.S. private sector development of commercial launch operations in accordance with existing direction.

The U.S. Government will not subsidize the commercialization of ELVs but will price the use of its facilities, equipment, and services by commercial ELV operators consistent with the goal of encouraging viable commercial ELV launch activities in accordance with existing direction.

Stimulate private sector commercial space activities. To stimulate private sector investment, ownership, and operation of civil space assets, the U.S. Government will facilitate private sector access to civil space systems, and encourage the private sector to undertake commercial space ventures without direct Federal subsidies.

Implementation: The U.S. Government will take the following initiatives:

Economic Initiatives. Tax laws and regulations which discriminate against commercial space ventures need to be changed or eliminated.

Legal and Regulatory Initiatives. Laws and regulations predating space operations need to be updated to accommodate space commercialization.

Research and Development Initiatives. In partnership with industry and academia, government should expand basic research and development which may have implications for investors aiming to develop commercial space products and services.

Initiatives to Establish and Implement a Commercial Space Policy. Since commercial developments in space often require many years to reach the production phase, entrepreneurs need assurances of consistent government actions and policies over long periods.

NASA, Department of Commerce, and Department of Transportation all have roles and will work cooperatively to develop and implement specific measures to foster the growth of private sector commercialization in space. A high level national focus for commercial space issues will be created through establishment of a Cabinet Council on Commerce and Trade (CCCT) Working Group on the Commercial Use of Space. The SIG(Space) will continue its role of coordinating the implementation of policy for the overall U.S. Space Program.

National Security Space Programs

Maintain assured access to space. The national security sector must pursue an improved assured launch capability to satisfy two specific requirements—the need for launch system complementary to the STS to hedge against unforeseen technical and operational problems, and the need for a launch system suited for operations and crisis situations.

Implementation: In order to satisfy the requirement for assured launch, the national security sector will pursue the use of a limited number of ELV's to complement the STS.

Pursue a long-term survivability enhancement program. The national security sector must provide for the survivability of selected, critical national security space assets to a degree commensurate with the value and utility of the support they provide. This will contribute to deterrence by helping to ensure that potential adversaries cannot eliminate vital U.S. space capabilities without considerable expenditure of their own resources.

Implementation: The high priority and emphasis on survivability reflected within the Department of Defense space programs will continue.

Stem the flow of advanced western space technology to the Soviet Union. The U.S. cannot be complacent about the increasing Soviet efforts to erase the U.S. advantage through vigorous Soviet research and development efforts and through technology transfer.

Implementation: All agencies of the Government will cooperate in order to prevent the transfer of space technology to the Soviet Union and to its allies, either directly or through third countries, if such transfer is potentially detrimental to the national security interests of the United States.

Continue to study space arms control options. The United States will continue to study space arms control options.

Implementation: The Senior Arms Control Policy Group will continue to study a broad range of possible options for space arms control. The studies will be undertaken with a view toward negotiations with the Soviet Union and other nations, compatible with national security interests. All actions will be conducted within the constraints of existing treaty commitments.

Insure that DOD space and space-related programs will support the Strategic Defense Initiative. In light of the uncertain long-term stability of offensive deterrence, an effort will be made to identify defensive means of deterring nuclear war. The U.S. has been investigating the feasibility of eventually shifting toward reliance upon a defensive concept. A program has been initiated to demonstrate the technical feasibility of enhancing deterrence through greater reliance on defensive strategic capabilities. The Department of Defense will posture its space activities so as to preserve options to support the demonstration of capabilities as they are defined and become available, and as justified by the state-of-the-art technology.

Maintain a vigorous national security space technology program to support the development of necessary improvements and new capabilities. The changing nature of the world environment presents new challenges at the same time as advances in technology present new opportunities.

Implementation: The Department of Defense will provide strong emphasis on advanced technology to respond to changes in the environment, to improve our space-based assets, and to provide new capabilities that capitalize on technological advances.

APPENDIX F-5

Public Law 98-575—October 30, 1984
98th Congress

An Act to facilitate commercial space launches, and for other purposes.

Public Law 98-575
98th Congress

An Act

To facilitate commercial space launches, and for other purposes.

Oct. 30, 1984
[H.R. 3942]

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

Commercial Space Launch Act.

SHORT TITLE

SECTION 1. This Act may be cited as the "Commercial Space Launch Act".

49 USC app. 2601 note.

FINDINGS

SEC. 2. The Congress finds and declares that—

49 USC app. 2601.

(1) the peaceful uses of outer space continue to be of great value and to offer benefits to all mankind;

(2) private applications of space technology have achieved a significant level of commercial and economic activity, and offer the potential for growth in the future, particularly in the United States;

(3) new and innovative equipment and services are being sought, created, and offered by entrepreneurs in telecommunications, information services, and remote sensing technology;

(4) the private sector in the United States has the capability of developing and providing private satellite launching and associated services that would complement the launching and associated services now available from the United States Government;

(5) the development of commercial launch vehicles and associated services would enable the United States to retain its competitive position internationally, thereby contributing to the national interest and economic well-being of the United States;

(6) provision of launch services by the private sector is consistent with the national security interests and foreign policy interests of the United States and would be facilitated by stable, minimal, and appropriate regulatory guidelines that are fairly and expeditiously applied; and

(7) the United States should encourage private sector launches and associated services and, only to the extent necessary, regulate such launches and services in order to ensure compliance with international obligations of the United States and to protect the public health and safety, safety of property, and national security interests and foreign policy interests of the United States.

PURPOSES

SEC. 3. It is therefore the purpose of this Act—

49 USC 2602.

(1) to promote economic growth and entrepreneurial activity through utilization of the space environment for peaceful purposes;

(2) to encourage the United States private sector to provide launch vehicles and associated launch services by simplifying and expediting the issuance and transfer of commercial launch licenses and by facilitating and encouraging the utilization of Government-developed space technology; and

(3) to designate an executive department to oversee and coordinate the conduct of commercial launch operations, to issue and transfer commercial launch licenses authorizing such activities, and to protect the public health and safety, safety of property, and national security interests and foreign policy interests of the United States.

DEFINITIONS

49 USC app. 2603.

SEC. 4. For purposes of this Act—

(1) "agency" means an executive agency as defined by section 105 of title 5, United States Code;

(2) "launch" means to place, or attempt to place, a launch vehicle and payload, if any, in a suborbital trajectory, in Earth orbit in outer space, or otherwise in outer space;

(3) "launch property" means propellants, launch vehicles and components thereof, and other physical items constructed for or used in the launch preparation or launch of a launch vehicle;

(4) "launch services" means those activities involved in the preparation of a launch vehicle and its payload for launch and the conduct of a launch;

(5) "launch site" means the location on Earth from which a launch takes place, as defined in any license issued or transferred by the Secretary under this Act, and includes all facilities located on a launch site which are necessary to conduct a launch;

(6) "launch vehicle" means any vehicle constructed for the purpose of operating in, or placing a payload in, outer space and any suborbital rocket;

(7) "payload" means an object which a person undertakes to place in outer space by means of a launch vehicle, and includes subcomponents of the launch vehicle specifically designed or adapted for that object;

(8) "person" means any individual and any corporation, partnership, joint venture, association, or other entity organized or existing under the laws of any State or any nation;

(9) "Secretary" means the Secretary of Transportation;

(10) "State", and "United States" when used in a geographical sense, mean the several States, the District of Columbia, the Commonwealth of Puerto Rico, American Samoa, the United States Virgin Islands, Guam, and any other commonwealth, territory, or possession of the United States; and

(11) "United States citizen" means—

(A) any individual who is a citizen of the United States;

(B) any corporation, partnership, joint venture, association, or other entity organized or existing under the laws of the United States or any State; and

(C) any corporation, partnership, joint venture, association, or other entity which is organized or exists under the laws of a foreign nation, if the controlling interest (as defined by the Secretary in regulations) in such entity is held by an individual or entity described in subparagraph (A) or (B).

GENERAL RESPONSIBILITIES OF THE SECRETARY AND OTHER AGENCIES

SEC. 5. (a) The Secretary shall be responsible for carrying out this Act, and in doing so shall— 49 USC app. 2604.

(1) encourage, facilitate, and promote commercial space launches by the private sector; and

(2) consult with other agencies to provide consistent application of licensing requirements under this Act and to ensure fair and equitable treatment for all license applicants.

(b) To the extent permitted by law, Federal agencies shall assist the Secretary, as necessary, in carrying out this Act.

REQUIREMENT OF LICENSE FOR PRIVATE SPACE LAUNCH OPERATIONS

SEC. 6. (a)(1) No person shall launch a launch vehicle or operate a launch site within the United States, unless authorized by a license issued or transferred under this Act. 49 USC app. 2605.

(2) No United States citizen described in subparagraph (A) or (B) of section 4(11) shall launch a launch vehicle or operate a launch site outside the United States, unless authorized by a license issued or transferred under this Act.

(3)(A) No United States citizen described in subparagraph (C) of section 4(11) shall launch a launch vehicle or operate a launch site at any place which is both outside the United States and outside the territory of any foreign nation, unless authorized by a license issued or transferred under this Act. The preceding sentence shall not apply with respect to a launch or operation of a launch site if there is an agreement in force between the United States and a foreign nation which provides that such foreign nation shall exercise jurisdiction over such launch or operation.

(B)(i) Except as provided in clause (ii) of this subparagraph, this Act shall not apply to the launch of a launch vehicle or the operation of a launch site in the territory of a foreign nation by a United States citizen described in subparagraph (C) of section 4(11).

(ii) If there is an agreement in force between the United States and a foreign nation which provides that the United States shall exercise jurisdiction over the launch of a launch vehicle or operation of a launch site in the territory of such nation by a United States citizen described in subparagraph (C) of section 4(11), no such United States citizen shall launch a launch vehicle or operate a launch site in the territory of such nation, unless authorized by a license issued or transferred under this Act. International agreements.

(b)(1) The holder of a launch license under this Act shall not launch a payload unless that payload complies with all requirements of Federal law that relate to the launch of a payload. The Secretary shall ascertain whether any license, authorization, or other permit required by Federal law for a payload which is to be launched has been obtained.

(2) If no payload license, authorization, or permit is required by any Federal law, the Secretary may take such action under this Act as the Secretary deems necessary to prevent the launch of a payload by a holder of a launch license under this Act if the Secretary determines that the launch of such payload would jeopardize the

public health and safety, safety of property, or any national security interest or foreign policy interest of the United States.

(c)(1) Except as provided in this Act, no person shall be required to obtain from any agency a license, approval, waiver, or exemption for the launch of a launch vehicle or the operation of a launch site.

(2) Nothing in this Act shall affect the authority of the Federal Communications Commission under the Communications Act of 1934 (47 U.S.C. 151 et seq.) or the authority of the Secretary of Commerce under the Land Remote-Sensing Commercialization Act of 1984 (15 U.S.C. 4201 et seq.).

AUTHORITY TO ISSUE AND TRANSFER LICENSES

49 USC app. 2606.

Sec. 7. The Secretary may, consistent with the public health and safety, safety of property, and national security interests and foreign policy interests of the United States, issue or transfer a license for launching one or more launch vehicles or for operating one or more launch sites, or both, to an applicant who meets the requirements for a license under section 8 of this Act. Any license issued or transferred under this section shall be in effect for such period of time as the Secretary may specify, in accordance with regulations issued under this Act.

LICENSING REQUIREMENTS

49 USC app. 2607.

Sec. 8. (a)(1) All requirements of Federal law which apply to the launch of a launch vehicle or the operation of a launch site shall be requirements for a license under this Act for the launch of a launch vehicle or the operation of a launch site, respectively, except to the extent provided in paragraph (2).

(2) If the Secretary determines, in consultation with appropriate agencies, that any requirement of Federal law that would otherwise apply to the launch of a launch vehicle or the operation of a launch site is not necessary to protect the public health and safety, safety of property, and national security interests and foreign policy interests of the United States, the Secretary may by regulation provide that such requirement shall not be a requirement for a license under this Act.

(b) The Secretary may, with respect to launches and the operation of launch sites, prescribe such additional requirements as are necessary to protect the public health and safety, safety of property, and national security interests and foreign policy interests of the United States.

(c) The Secretary may, in individual cases, waive the application of any requirement for a license under this section if the Secretary determines that such waiver is in the public interest and will not jeopardize the public health and safety, safety of property, or any national security interest or foreign policy interest of the United States.

LICENSE APPLICATION AND APPROVAL

49 USC app. 2608.

Sec. 9. (a) Any person may apply to the Secretary for issuance or transfer of a license under this Act, in such form and manner as the Secretary may prescribe. The Secretary shall establish procedures and timetables to expedite review of applications under this section and to reduce regulatory burdens for applicants.

(b) The Secretary shall issue or transfer a license to an applicant if the Secretary determines in writing that the applicant complies and will continue to comply with the requirements of this Act and any regulation issued under this Act. The Secretary shall include in such license such conditions as may be necessary to ensure compliance with this Act, including an effective means of on-site verification that a launch or operation of a launch site conforms to representations made in the application for a license or transfer of a license. The Secretary shall make a determination on any application not later than 180 days after receipt of such application. If the Secretary has not made a determination within 120 days after receipt of such application, the Secretary shall inform the applicant of any pending issues and of actions required to resolve such issues.

(c) The Secretary, any officer or employee of the United States, or any person with whom the Secretary has entered into a contract under section 14(b) of this Act may not disclose any data or information under this Act which qualifies for exemption under section 552(b)(4) of title 5, United States Code, or is designated as confidential by the person or agency furnishing such data or information, unless the Secretary determines that the withholding of such data or information is contrary to the public or national interest.

SUSPENSION, REVOCATION, AND MODIFICATION OF LICENSES

49 USC app. 2609.

SEC. 10. (a) The Secretary may suspend or revoke any license issued or transferred under this Act if the Secretary finds that the licensee has substantially failed to comply with any requirement of this Act, the license, or any regulation issued under this Act, or that the suspension or revocation is necessary to protect the public health and safety, safety of property, or any national security interest or foreign policy interest of the United States.

(b) Upon application by the licensee or upon the Secretary's own initiative, the Secretary may modify a license issued or transferred under this Act, if the Secretary finds that the modification will comply with the requirements of this Act.

(c) Unless otherwise specified by the Secretary, any suspension, revocation, or modification by the Secretary under this section—

(1) shall take effect immediately; and

(2) shall continue in effect during any review of such action under section 12 of this Act.

(d) Whenever the Secretary takes any action under this section, the Secretary shall notify the licensee in writing of the Secretary's finding and the action which the Secretary has taken or proposes to take regarding such finding.

EMERGENCY ORDERS

Prohibition. 49 USC app. 2610.

SEC. 11. (a) The Secretary may terminate, prohibit, or suspend immediately the launch of a launch vehicle or the operation of a launch site which is licensed under this Act if the Secretary determines that such launch or operation is detrimental to the public health and safety, safety of property, or any national security interest or foreign policy interest of the United States.

(b) An order terminating, prohibiting, or suspending any launch or operation of a launch site licensed by the Secretary under this Act shall take effect immediately and shall continue in effect during any review of such order under section 12.

ADMINISTRATIVE AND JUDICIAL REVIEW

49 USC app. 2611.

SEC. 12. (a)(1) An applicant for a license and a proposed transferee of a license under this Act shall be entitled to a determination on the record after an opportunity for a hearing in accordance with section 554 of title 5, United States Code, of any decision of the Secretary under section 9(b) to issue or transfer a license with conditions or to deny the issuance or transfer of such license. An owner or operator of a payload shall be entitled to a determination on the record after an opportunity for a hearing in accordance with section 554 of title 5, United States Code, of any decision of the Secretary under section 6(b)(2) to prevent the launch of such payload.

(2) A licensee under this Act shall be entitled to a determination on the record after an opportunity for a hearing in accordance with section 554 of title 5, United States Code, of any decision of the Secretary—

(A) under section 10 to suspend, revoke, or modify a license; or

(B) under section 11 to terminate, prohibit, or suspend any launch or operation of a launch site licensed by the Secretary.

(b) Any final action of the Secretary under this Act to issue, transfer, deny the issuance or transfer of, suspend, revoke, or modify a license or to terminate, prohibit, or suspend any launch or operation of a launch site licensed by the Secretary or to prevent the launch of a payload shall be subject to judicial review as provided in chapter 7 of title 5, United States Code.

REGULATIONS

49 USC app. 2612.

SEC. 13. The Secretary may issue such regulations, after notice and comment in accordance with section 553 of title 5, United States Code, as may be necessary to carry out this Act.

MONITORING OF ACTIVITIES OF LICENSEES

49 USC app. 2613.

SEC. 14. (a) Each license issued or transferred under this Act shall require the licensee—

(1) to allow the Secretary to place Federal officers or employees or other individuals as observers at any launch site used by the licensee, at any production facility or assembly site used by a contractor of the licensee in the production or assembly of a launch vehicle, or at any site where a payload is integrated with a launch vehicle, in order to monitor the activities of the licensee or contractor at such time and to such extent as the Secretary considers reasonable and necessary to determine compliance with the license or to carry out the responsibilities of the Secretary under section 6(b) of this Act; and

(2) to cooperate with such observers in the performance of monitoring functions.

(b) The Secretary may, to the extent provided in advance by appropriation Acts, enter into a contract with any person to carry out subsection (a)(1) of this section.

USE OF GOVERNMENT PROPERTY

49 USC app. 2614.

SEC. 15. (a) The Secretary shall take such actions as may be necessary to facilitate and encourage the acquisition (by lease, sale, transaction in lieu of sale, or otherwise) by the private sector of launch property of the United States which is excess or is otherwise not needed for public use and of launch services, including utilities, of the United States which are otherwise not needed for public use.

(b)(1) The amount to be paid to the United States by any person who acquires launch property or launch services, including utilities, shall be established by the agency providing the property or service, in consultation with the Secretary. In the case of acquisition of launch property by sale or transaction in lieu of sale, the amount of such payment shall be the fair market value. In the case of any other type of acquisition of launch property, the amount of such payment shall be an amount equal to the direct costs (including any specific wear and tear and damage to the property) incurred by the United States as a result of the acquisition of such launch property. In the case of any acquisition of launch services, including utilities, the amount of such payment shall be an amount equal to the direct costs (including salaries of United States civilian and contractor personnel) incurred by the United States as a result of the acquisition of such launch services.

(2) The Secretary may collect any payment for launch property or launch services, with the consent of the agency establishing such payment under paragraph (1).

(3) The amount of any payment received by the United States for launch property or launch services, including utilities, under this subsection shall be deposited in the general fund of the Treasury, and the amount of a payment for launch property (other than launch property which is excess) and launch services (including utilities) shall be credited to the appropriation from which the cost of providing such property or services was paid.

(c) The Secretary may establish requirements for liability insurance, hold harmless agreements, proof of financial responsibility, and such other assurances as may be needed to protect the United States and its agencies and personnel from liability, loss, or injury as a result of a launch or operation of a launch site involving Government facilities or personnel.

LIABILITY INSURANCE

SEC. 16. Each person who launches a launch vehicle or operates a launch site under a license issued or transferred under this Act shall have in effect liability insurance at least in such amount as is considered by the Secretary to be necessary for such launch or operation, considering the international obligations of the United States. The Secretary shall prescribe such amount after consultation with the Attorney General and other appropriate agencies. 49 USC app. 2615.

ENFORCEMENT AUTHORITY

SEC. 17. (a) The Secretary shall enforce this Act. The Secretary may delegate the exercise of any enforcement authority under this Act to any officer or employee of the Department of Transportation or, with the approval of the head of another agency, any officer or employee of such agency. 49 USC app. 2616.

(b) In carrying out this section, the Secretary may—

(1) make investigations and inquiries, and administer to or take from any person an oath, affirmation, or affidavit, concerning any matter relating to enforcement of this Act; and

(2) pursuant to any lawful process—

(A) enter at any reasonable time any launch site, production facility, or assembly site of a launch vehicle, or any site where a payload is integrated with a launch vehicle, for the purpose of inspecting any object which is subject to this Act and any records or reports required by the Secretary to be made or kept under this Act; and

(B) seize any such object, record, or report where there is probable cause to believe that such object, record, or report was used, is being used, or is likely to be used in violation of this Act.

PROHIBITED ACTS

49 USC app. 2617.

SEC. 18. It is unlawful for any person to violate a requirement of this Act, a regulation issued under this Act, or any term, condition, or restriction of any license issued or transferred by the Secretary under this Act.

CIVIL PENALTIES

49 USC app. 2618.

SEC. 19. (a) Any person who is found by the Secretary, after notice and opportunity to be heard on the record in accordance with section 554 of title 5, United States Code, to have committed any act prohibited by section 18 shall be liable to the United States for a civil penalty of not more than $100,000 for each violation. Each day of a continuing violation shall constitute a separate violation. The amount of such civil penalty shall be assessed by the Secretary by written notice. The Secretary may compromise, modify, or remit, with or without conditions, any civil penalty which is subject to imposition or which has been imposed under this section.

(b) If any person fails to pay a civil penalty assessed against such person after the penalty has become final or if such person appeals an order of the Secretary and the appropriate court has entered final judgment in favor of the Secretary, the Secretary shall recover the civil penalty assessed in any appropriate district court of the United States.

(c) For purposes of conducting any hearing under this section, the Secretary may (1) issue subpoenas for the attendance and testimony of witnesses and the production of relevant papers, books, documents, and other records, (2) seek enforcement of such subpoenas in the appropriate district court of the United States, and (3) administer oaths and affirmations.

CONSULTATION

Defense and national security.
49 USC app. 2619.

SEC. 20. (a) The Secretary shall consult with the Secretary of Defense on all matters, including the issuance or transfer of each license, under this Act affecting national security. The Secretary of Defense shall be responsible for identifying and notifying the Secretary of those national security interests of the United States which are relevant to activities under this Act.

(b) The Secretary shall consult with the Secretary of State on all matters, including the issuance or transfer of each license, under this Act affecting foreign policy. The Secretary of State shall be responsible for identifying and notifying the Secretary of those foreign policy interests or obligations of the United States which are relevant to activities under this Act.

(c) The Secretary shall consult with other agencies, as appropriate, in order to carry out the provisions of this Act.

RELATIONSHIP TO OTHER LAWS AND INTERNATIONAL OBLIGATIONS

Prohibitions.
49 USC app.
2620.

SEC. 21. (a) No State or political subdivision of a State may adopt or have in effect any law, rule, regulation, standard, or order which is inconsistent with the provisions of this Act. Nothing in this Act shall preclude a State or a political subdivision of a State from adopting or putting into effect any law, rule, regulation, standard, or order which is consistent with this Act and is in addition to or more stringent than any requirement of or regulation issued under this Act. The Secretary may, and is encouraged to, consult with the States to simplify and expedite the approval of space launch activities.

(b) A launch vehicle or payload shall not, by reason of the launching of such vehicle or payload, be considered an export for purposes of any law controlling exports.

(c) Nothing in this Act shall apply to—

(1) any—

(A) launch or operation of a launch vehicle,

(B) operation of a launch site, or

(C) other space activity,

carried out by the United States on behalf of the United States; or

(2) any planning or policies relating to any such launch, operation, or activity.

(d) The Secretary shall carry out this Act consistent with any obligation assumed by the United States in any treaty, convention, or agreement that may be in force between the United States and any foreign nation. In carrying out this Act, the Secretary shall consider applicable laws and requirements of any foreign nation.

REPORT ON LEGISLATION

Report.
49 USC app.
2621.

SEC. 22. (a) Not later than the last day of each fiscal year ending after the date of enactment of this Act and before October 1, 1989, the Secretary shall submit to the Committee on Science and Technology of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate a report describing all activities undertaken under this Act, including a description of the process for the application for and approval of licenses under this Act and recommendations for legislation that may further commercial launches.

(b) Not later than July 1, 1985, the Secretary shall submit to the Committee on Science and Technology of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate a report which identifies Federal statutes, treaties, regulations, and policies which may have an adverse effect on commercial launches and include recommendations on appropriate changes thereto.

SEVERABILITY

49 USC app.
2622.

SEC. 23. If any provision of this Act, or the application of such provision to any person or circumstance, is held invalid, the remainder of this Act and the application of such provision to any other person or circumstance shall not be affected by such invalidation.

AUTHORIZED APPROPRIATIONS

49 USC app. 2623.

SEC. 24. There are authorized to be appropriated to the Secretary $4,000,000 for fiscal year 1985.

EFFECTIVE DATE

49 USC app. 2601 note.

SEC. 25. (a) Except for section 15 and the authority to issue regulations, this Act shall take effect 180 days after the date of enactment of this Act.

(b) Section 15 shall take effect on the date of enactment of this Act, except that nothing in this Act shall affect any agreement, including negotiations which are substantially completed, relating to the acquisition of launch property or launch services of the United States entered into on or before the date of enactment of this Act between the United States and any private party.

Regulations.

(c) Regulations to implement this Act shall be promulgated not later than 180 days after the date of enactment of this Act.

Approved October 30, 1984.

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